MINUTES
of the
EXPLOSIVES SAFETY SEMINAR
on
HIGH-ENERGY SOLID PROPELLANTS

Held at the

Naval Propellant Plant, Indian Head, Maryland

on

10-11 June 1959

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Armed Services Explosives Safety Board
Washington 25, D. C.

PREFACE

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PREFACE

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Further exchange of information on how to prevent explosive accidents is encouraged. It is suggested that any questions on portions of discussions be directed to the appropriate speakers, or their sponsoring agencies, rather than to the Armed Services Explosives Safety Board. This will expedite answers and will promote direct exchange of information between principals, which can be so effective in promoting safety.

Considerable interest was expressed, at the Seminar, in uniformity of hazard classification and the effectiveness of dividing walls in preventing propagation. A procedure for the establishment of uniform hazard classifications by the Services has been approved by the Board and should appear in the near future as a joint publication. A work group is reviewing available information on effectiveness of dividing walls and will submit its findings and recommendations to the Board as soon as practicable.

Please advise the Armed Services Explosives Safety Board of any corrections to be made in these minutes, and errata sheets will be prepared.

The contribution to the cause of promoting explosives safety, by those who devoted valuable time and effort to this Seminar, is very much appreciated.

W. T. Jenkins
W. T. JENKINS
Captain, USN
Chairman, Armed Services Explosives Safety Board

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EXTRACT OF MINUTES

SOLID PROPELLANT SEMINAR

NAVAL PROPELLANT PLANT, INDIAN HEAD, MARYLAND

10 - 11 JUNE 1959

Captain G. T. Atkins: Admiral Hubbard, Mr. Marsh, Captain Jenkins, gentlemen, I am Captain Atkins, Commanding Officer of the Naval Propellant Plant. It gives me and all of us here great pleasure to welcome you to the first solid propellant seminar sponsored by the Armed Services Explosives Safety Board. We here consider it a great privilege to be your host for this meeting. We want to thank you for leaving your jobs and coming this far in this hot weather to be with us, and we're going to try to make your stay here as comfortable and useful to you as we can. We have a pink booklet that each of you should get a copy of. This gives the schedule for this meeting and gives some other information. If we have overlooked anything that will help you or help the seminar, please let any of us here at the plant know. The official liaison officer is Lt. Commander Buckles. He is our Safety Officer and he will be on hand all the time you are here to help you, but if you see any of us here, please let us know what we can do for you.

We, here, are very interested in the subject of this seminar. We have made solid propellants here for sixty-two years, and in that time, over the years, new propellants have come in and have replaced the old ones and we have had to put in new machinery and work out new methods. In the last few years, this tempo has increased because guided missiles and ballistic missiles require very high impulse and relatively small quantities of propellant. This means that we are faced with having to manufacture propellants that use ingredients that are very hazardous. We make stuff with hazards that we wouldn't have thought possible when we were making large quantities of propellant. It means that

we have to get special machinery and go to pretty high costs in order to get the very best propellant out. In order to keep the solid propellant technology advancing, we have to keep looking to the future where we are going to have to get higher and higher impulses. If we don't, the solid propellant business will quickly fall behind the liquid propellants. In order to use solid propellants, we feel one of the real stumbling blocks is: how are we going to process these things without having explosions or serious fires? If we don't overcome this problem, there is going to be a feeling that solid propellants are not safe to make, or even to use, and we in the solid propellant business are going to lose the one big advantage that we have had relative to liquid propellants recently. Most of us feel that a solid propellant is something that is dependable and safe; but, if we have troubles in making the stuff and we have to tell the research people to slow down in what they are putting into solid propellants because we can't handle it, then we're pretty well handicapped -- pretty well licked. We feel that the biggest thing we can do right now to help is to have other people like yourselves get together and talk over what we know about safety and interchange ideas. That is why we are so interested in this meeting today. Now, it is my pleasure to introduce Rear Admiral Miles H. Hubbard. He has recently come to Washington from duty in the Pacific, where he was on the Joint Staff, Commander-in-Chief Far East Command, and then later Commander, Cruiser Division. Admiral Hubbard has always been in Navy Ordnance, and at present, he is the Deputy Chief of the Navy's Bureau of Ordnance. Admiral Hubbard.

<u>Rear Admiral M. H. Hubbard, Deputy Chief, BuOrd, Navy:</u> Captain Atkins, Mr. Marsh, gentlemen: I am very happy to add my welcome to that of Captain Atkins, and also Admiral Stroop who, in a very few moments, will be on his way to the west coast. I am sorry that I will not be able to remain and participate in this meeting because of the subjects in which I am personally greatly interested; but, the usual crisis has occurred and I am due back in Washington. During the course of this seminar, you will hear a lot about the technical aspects of explosives safety. This is a good solid subject, and there is a large area to cover. As you read the roster of the speakers to follow, you will see that we have people who are known for their professional knowledge of the subject here to address you. I will not term them "experts". The word sometimes has undesirable connotations. When I was in Pensacola in 1929, there was a general saying that: "The only good aviators were the dead ones." This, of course, was not true, but there are a lot of prematurely dead people who have been in the explosives business. Danger can be overstressed. Our purpose in the Ordnance game is to be able to kill the enemy. There has never been a better way to do this than through the proper application of explosives. With the years, and constant study groups such as this, we were able to deliver our so-called "conventional weapons" with a marked degree of safety for our own people. Nevertheless, we sometimes had accidents (fires and explosions) including some very bad ones. We never reached the safety ideal since we couldn't completely eliminate such accidents but we have reduced

their frequency by use of methods quite familiar to you gentlemen. Present day Ordnance has increased in sophistication and complexity, both in the end explosion and the propulsion to deliver it to the target. The safety problems have grown in proportion to the increased complexity of the missile and weapon. There are many more completely unknown factors to study, both in behavior and manufacturing processes, than we have ever faced before. We are dealing with more sensitive materials and tremendously greater forces than faced us in the past. It is no longer a chemist's job alone. For example, electrical, electronic, and mechanical engineers are needed on the team along with other professionals. Gentlemen, we have a big job ahead of us. This seminar gives us an opportunity to exchange ideas and to tell each other what we have found to be fact, or, perhaps more importantly, what we have found to be false. Communications is the heart of any organization, and this task is too big for any one small group. Many shoulders will be needed to push this wagon, and unfortunately, there is not much axle grease in the form of money to make the job any easier. This does not worry me too much, for this is a job for the good of the United States and the public interest never lacks support from a group such as this. Your past record has never developed a more challenging new problem than that with which you are now faced. Again, gentlemen, I am sorry that I cannot stay and participate in this meeting, but I know a great deal of good will come of it.

Captain Atkins: Thank you, Admiral Hubbard. It is now my pleasure to introduce the Chairman of the Armed Services Explosives Safety Board who has sponsored this seminar, and who will act as the moderator. Captain Jenkins has had a long and varied connection with Ordnance throughout his career. He has served at the Naval Proving Ground, has been head of the Ordnance and Gunnery Department at the Naval Academy, has had other Ordnance jobs both ashore and afloat, and, of course, in his present position, he gets around to see many installations and to inquire into safety matters so I think we are very fortunate to have him as our moderator. Incidentally, I used to work for Captain Jenkins for awhile, many years ago when he ran the Shell House down at the Naval Proving Ground at Dahlgren, and had to check in ammunition to make tests. In those days, we didn't have all the hired help that we have now. I was a Lieutenant then and I used to have to climb a 40-foot ladder and drop a fuze down a pipe to give it the 40-foot drop test, and I think Captain Jenkins was even then a very safety-conscious man. I think his thought was that you shouldn't get more than one fuze together with another, so I had to make a separate 40-foot trip for every fuze to be tested. You see, we are dealing with a hard man here. Captain Jenkins.

Captain W. T. Jenkins, USN, Chairman, ASESB: Captain Atkins, Mr. Marsh, and distinguished guests: I want to mention right at the start how pleased we are that the Bureau of Ordnance kindly consented and enthusiastically agreed to sponsor this first seminar on the subject of safety with respect to high-energy solid propellants, and for making funds available for the reception which is coming off this

afternoon and which Captain Atkins mentioned to you. I want to thank Captain Atkins and his many associates for the wonderful arrangements they have made:

Setting up the tour and furnishing a most impressive exhibit of many of our high-energy solid propellants in the various stages of manufacture.

In making facilities so comfortable for us; putting in this air conditioning. This was a crash program; they put in two air conditioning units on Friday to make our lives endurable here.

Then, the nice arrangements in the BOQ, etc., so I certainly do appreciate that on behalf of the Board and, I hope, all of us present.

In appearing before this high-level array of talent, assembled from far and wide, and covering a large portion of the explosives profession, I might say that it is with a decided feeling of humility on my part. I realize that I am standing in the halls of the mighty as it were, before my peers, like a lawyer arguing his first case before the Supreme Court. However, the job of the Board of which I am Chairman is safety, and in this new field of high-energy solid propellants, fast-burning and yet almost mass detonating borderline materials, incidents have been happening all too frequently with considerable property damage but, so far, I am glad to say, loss of life and injuries have been relatively small. None of us know all the answers in this business, in this new field, by any means. If we did, there would be no need for this seminar, but I and my associates felt that by calling this group together, trading and sharing ideas, we might improve the cause of safety tremendously. You are all familiar with that old axiom in the explosives safety field, "You never know about the lives you save, it's only the ones which are lost which you hear about."

Many of you are already aware of the organization, functions and operations of the ASESB, but perhaps some of you are not especially those from civilian industry, so I thought I would give you a brief outline:

On July 2, 1926, two of our largest military explosives installations were destroyed as a result of lightning striking one of the storage magazines, containing over a million pounds of bulk TNT and loaded projectiles; namely, Lake Denmark and Picatinny Arsenal. Financial losses at that time were in the neighborhood of seventy-five million dollars which, in those days of course, was not "hay". The personnel losses were approximately nineteen, only, due to the fact that it was a Saturday afternoon which was a nonwork period and most of the permanent personnel were off the station. As a result of this incident, the Board, in an earlier form, was established by Congressional Act. It is now composed of three officer members serving in a part-time capacity, one each from the Army, Navy and Air Force, plus alternates from each of the Services, and myself as the full-time Chairman. The Navy, incidentally, is represented by Bureau of Ordnance membership. In addition, there is a

permanent staff of one Army, Navy and Air Force officer plus a number of civilian technicians and administrative assistants. Each Service designates the Chairman in rotation for a two-year period, normally from the permanent staff officers. This tri-Service Department of Defense Board reports to the Secretary of the Army as the executive agency. The Board itself is generally charged with preventing hazardous conditions from arising which would unduly endanger life and property in the handling of ammunition and explosives. In carrying out this function, we have survey engineers who inspect representative ammunition manufacturing and handling facilities under Government control. We strive for uniformity in procedures between the three Services and we review construction plans for modifications, or initial construction, at all ammunition handling and storage facilities. In making our surveys, we do not attempt to cover every nut and bolt or go into every detail; however, we do review all operations which are in progress at the time of the inspection, survey representative storage sites to insure that there are no conditions existing which would cause undue loss of life or property, and we point out any violations which we see in the course of our survey. With out inspectors in the field, reviews of designs and plans, if possible, before they are placed into effect, insuring conformity with existing criteria, and providing for an exchange of information such as this seminar, although we cannot prevent all property damage by any means or eliminate all personnel casualties, we can reduce tremendously the frequency of incidents in this so-called game of "playing with fire".

Captain Atkins is a former Navy member of the ASESB. Since taking over command of the Naval Propellant Plant and after a few problems of his own, he discussed with me the advisability of having a get-together of people in the field to trade ideas and possibly benefit from it. Normally, in competitive industry, some people would not feel hurt in seeing the other fellow's plant blown up; however, in this explosives industry, a safety procedure which saves the other fellow's plant can possibly save your own and that is where we come in. The idea of this conference "grew like Topsy". At the start, our concern was whether we were going to have sufficient quantity and quality of material and talent to justify this seminar, but I am glad to say, it didn't take us very long before our main concern was over having too much of it. As far as I can ascertain now, the majority of suggested subject matter has been included in this seminar. With such a list of subject matter as we have, and such an imposing array of talent to discuss and present it, we are going to have a fairly tight schedule. However, at the start, it looks like we will be able to cover it satisfactorily. Just one amusing anecdote in that line:

I once heard a professor of public speaking remark that, if someone told you that you could speak for one-half hour, to make it twenty minutes, if for twenty minutes make it ten, and if someone told you to speak as long as you wanted, make it five.

So, sort of bear that in mind as we go through the major details of this seminar. Actually, in making up the agenda, we have provided for numerous breaks to take in a little of the slack and possibly, we can accomplish much in informal discussions between individuals during breaks and after hours on subjects in which certain people are particularly interested. We do not intend to settle all problems at this seminar by any means. This is the first one and merely a beginning of what I hope will come in the future. Much of the material in this seminar, I feel, will be unclassified; however, there are instances where classified material will be discussed. I assume that all of you have been properly checked in now on your security clearance, and I would appreciate it if the speakers would indicate the classification when they present material that is higher than "unclassified". The same applies to discussions by individuals from the floor. As stated in the Agenda forwarding letter, where speakers have formal papers to present, it would help if a copy could be given to the recorder. Another little detail: in floor discussions which will come, I wish you would raise your hand, wait for the mike, and when you get the mike announce your name and your company.

Now, I would like to introduce the following individuals who will be my assistants and "strong right arm" during the proceedings:

Mr. H. F. Harris, Safety Engineer, ASESB.
Mr. Louis Jezek, OCO, Department of the Army.
Mr. H. M. Roylance, BuOrd, Department of the Navy.
Mr. D. E. Endsley, DCS/Mat, Department of the Air Force.

This panel will assist in any problems and discussions which come up and which, I hope, will lead to many of the answers you want. I might add that these four people, in addition to being my "strong right arm", were largely responsible for setting up what, I think, is a very effective agenda. Because of other problems in which I was involved, I could not get into the minute details on it, and I think they did a far better job on it without my detailed assistance. I certainly want to give them my thanks, especially Mr. Harris, for doing all the administrative detail in working up this agenda.

Another gentleman, important by his presence here, is Mr. D. E. Miller, Office of the General Counsel, Office Secretary of the Army. He is here to see that we don't form any "cartels" during the proceedings and to defend us if we do. Are there any questions from anyone before we have a break, and then get on with the main proceedings?

In developing the agenda, we decided that the best way to start would be with an historical sketch of the development and conditions existing with respect to propellants. I know of no better-qualified person to handle this subject than Mr. Henry Marsh, who is a Board Consultant on whom we lean heavily for guidance, keeping us in touch

with civilian industry. He is a former manager of the Smokeless Powder Division of the Hercules Powder Company, a former Deputy Assistant Secretary of the Army for Logistics, and is Vice President of the American Ordnance Association, and in charge of all its technical committees. I say this with due honor and respect, that he is one of the old-time experts in the field and literally grew up in this business. I have asked him to bring us up along the rugged road which he followed. Mr. Marsh.

Mr. Henry N. Marsh, Vice President, American Ordnance Association:

Mr. Chairman, Captain Atkins, gentlemen: it was an excellent idea to get this fine group together here at this historic spot to discuss some of the problems that arise in this interesting field of high-energy solid propellants. I am delighted to see so many old friends, and I hope to meet the many new faces who are coming into this field. I also want to set you straight. An error in the preliminary agenda listed me as a former Vice President of Hercules Powder Company. I hold such a job in the American Ordnance Association, but never did at Hercules Powder Company. To get in a plug here, I sincerely hope that every person in the room who is not now a member of the AOA will join it, and will apply for appointment to serve in the technical divisions and sections which are so actively engaged in helping the Armed Services in problems connected with the Space Age. Everyone in the room would be interested, either in the activities of the Propellant and Explosives Section of the Materials Division or some section of the Missiles and Astronautics Division.

I have been given a job of reminiscing a bit about propellants. When first exposed to smokeless powder 41 years ago, we were involved in World War I and, if my memory is any good, there were four or five plants active - Kenvil, Carney's Point, Picatinny and Indian Head - supplemented before the war ended by Union Powder at Parlin, Aetna Plant at Mt. Union, Pennsylvania, and by the big U. S. Plants at Old Hickory, Tennessee and at Nitro, West Virginia. It was certainly an art and not a science. There was little or no recognition of risks with which we are now familiar, and little concern for proper ventilation, spark-proof tools, fire resistant clothing, elimination of static hazards, remote controls, limitation on closing rates of presses, etc. We have learned, through bitter experience, about the need for attention to such matters. Most of the essential operating procedures and compositions were closely-guarded trade secrets, and while accident experience was exchanged, it was always done in such fashion as to limit information on know-how and process, and was not of too much use. After World War I, we went through that wonderful period when it was agreed that there would be no more wars, and we sank much of our Navy and scrapped Old Hickory, Nitro, and Mt. Union. The only activity of note was commercial production at Carney's Point and Kenvil, and limited activity at Indian Head and Picatinny. In World War I, the U. S.

cannon powder was all pyro from 12.6% nitrocellulose, though Hercules made great tonnages of cordite for the United Kingdom under a one-page contract directing production of a single size in unlimited quantity at a fixed price, so long as existing sources of acetone were not touched. The major trouble was fire. There were mixer fires. We learned to open vent ports around the shaft bearings and tried to eliminate tramp metal from the nitrocellulose, and we put thin lead covers instead of heavy steel ones on the mixers to reduce severity of mixer shots. We tried to teach the men to start presses slowly to limit compression ignition. We started to improve ventilation, particularly in the cutting rooms, to avoid drunken operators at the end of the shift. We burned so many blender towers that there was an urge to perfect some other scheme, but we learned to do this by remote control and limited crews. I often remember, with cold chills, watching the blue fire of static playing around over the powder on a cold night at the top of the blender. During the period between the wars, some development went on and DuPont perfected FNH cannon and the IMR rifle powders now using 13.15-13.20% nitrocellulose, and Hercules made the first sheet powder charges by a solventless process for the trench mortars. Before the U. S. was involved directly in World War II, there was considerable activity in helping Nationalist China fight with Japan, and early efforts to help the United Kingdom and France, at the Chickasaw and Belvidere plants. Then the U. S. got underway progressively with Indiana and Radford, and then Alabama, Oklahoma, Sunflower, Badger, etc. Soon there was a different atmosphere. The real need of national defense started a free exchange of information on compositions, processes, and equipment, through the industry integrating committees. The wall was breached, and this has continued ever since under the leadership of our hosts, ASESB, and through OAC--a ready exchange of anything that will improve safety. As we progress further into the present field of high-energy compositions which we will discuss here today and tomorrow, this is all important - let no one hold back anything that may save a life or that may intensify our effort. There has always been and will always be differences of opinion on the best way to reach a given goal. In each case, be sure you tell us the advantages of your way. Let us now examine the field of our interest and some of the places we should be most alert for possible trouble. They are all, to a degree, interconnected but let's look at a few of them:

a. The introduction of new and different ingredients.
b. The introduction of different equipment.
c. The introduction of new processes.
d. Scaling up to much larger equipment.

Recognizing the competitive attitude that is inevitable in a free economy and not wishing to point a finger at former competitors, most all of the examples that I may use to illustrate a point will come from past experience. This might appear to indicate that Hercules was not as smart as others. That I do not believe even though we, like all the rest of you, at times have been guilty of overlooking the obvious answer

under the question of new and different ingredients. Every effort has been made over the years to find a safer, better liquid explosive ingredient than straight nitroglycerin. Many have been tried. Nearly every one of them has some obvious advantage but as an economical, high-energy material, it's hard to beat. Many of its disadvantages have been bypassed by the perfection of the continuous nitrator and this, in turn, has been recently improved in another major respect. Enough of that. A good example came in the earlier preparation of triple base propellant, incorporating nitroguanidine into double base mixes. Fires in the mixer proceeded almost instantly to detonation. This effect does not last long after the crystals become solvent wet, but during the period, an explosion risk exists. For this reason, remote charging and operation become necessary. A similar experience came in solventless sheet manufacture. A certain amount of thin-edge trim material accumulated. If effort was made to reincorporate this material on the mixing rolls along with the normal feed stock, severe shots resulted. The solution--burning the material is the economic solution. Under Class B--use of different equipment. It was quite obvious that much time and effort might be saved if solvent or solventless rocket powder could be worked and extruded using a rubber or plastic type extruder instead of the expensive solventless press. This has been tried repeatedly by several different companies. The longest successful operation so far has only been a matter of hours. We mentioned earlier the problems that arose with the tower blenders that demanded their replacement. Two radically different solutions have been perfected--one by DuPont, using a low tower and air transport, and one by use of sizable copper blending barrel, by Hercules. The records of both systems have been reasonably good. The use of continuous process for making nitroglycerin, PETN, TNT, and RDX had many advantages, but the development was marked by disaster after disaster. Continued effort has solved these problems and many further improvements have been added. That fundamental ingredient, nitrocellulose, has always been made by a batch process until about three years ago. It was hard work and, particularly with high-grade, there were too many accidents. Hercules has recently perfected a continuous process, more compact, less hazardous and lower exposure. Three men now do the work previously requiring 44. Under Class C--use of new process. I will cite only one horrible example. In the manufacture of single base, one major problem is solvent recovery. With the large demands that developed early in World War II, Hercules introduced an entirely new type of unit of much larger capacity, a Class D type of problem as well. It was put in service on a United Kingdom contract. Early in its use, accidental ignition occurred in one of the units. The fire lasted about five seconds followed by 3 or 4 detonations demolishing the plant with large loss of life. The powder involved was solvent wet single-base powder for 8" gun. Now what were the differences from previous practices? The unit was several times larger than previous ones, high-grade nitrocellulose was used in this FNH composition, and the unit was built

of aluminum sheet and a new design. In the subsequent investigations the answer was found. It was none of those things, but the failure to recognize in the new design that there was much greater depth in the drying layer than before, and this, coupled with ignition on the bottom of the layer from a source never identified. For repetition, bottom ignition was essential and depth of layer must exceed a definite critical point which varies with web, temperature, type of perforation and calorific value of composition. Degree of confinement seems to have no influence. World War II saw the introduction into the U. S. of the first large-scale production of solventless powder, only known before in trench mortar charges and in one type of shotgun powder. Techniques for this were built up on the basis of one small group visit to the United Kingdom, and the early production was cursed with a plethora of fires so that Reader's Digest carried an article titled: "Hell Breaks Loose in Kansas." The record of roll fires averaged for a time over 1,000 a month. High-speed sprinklers to protect the workers and equipment, remote control charging, controlled moisture of feed stock, and elimination of certain types of feed stock presently worked the fire rate on this enormous plant down to less than 30 a month. Flameproof clothing was a great help. Again this required the design and operating technique for an entirely different type of press and the present determination that 15" diameter baskets were the largest that could be economically used, so 7" diameter grain is the upper limit, and preferably a bit smaller. And now we are in an area of cast and composite types and cast composites with apparently no upper limit on size, and all sorts of high-energy combinations. That's why we are here today and tomorrow. Let's exchange ideas freely and hope to avoid any more serious accidents.

Captain Jenkins: Mr. Marsh mentioned "the hard way". The thought just occurred to me, that when I first went to Dahlgren in 1937, they hadn't had a fire there in years. The fire department was very inactive. Three weeks after I arrived there, they had a fire in the shell house, so I had a good one fast and the hard way too. Mr. Russel Perkins, Chief of the Explosives Branch, Technical Division, of the ASESB, will possibly contrast some of Mr. Marsh's remarks with the vastness of current facilities. You hear a lot of talk of weapons in the megatons and multi-megaton range quite frequently. I'll never forget my amazement when I first saw a rocket motor with an 160,000 pound thrust and I came back and pictured every stowage structure as having a weapon of that size and nature. They aren't all that way, but recently we all think in terms of megatons in just a normal conversation.

Mr. R. G. Perkins, Chief, Explosives Branch, Technical Division, ASESB: Anything that I would say after the opening speeches that you have heard would be anticlimactic, and anything I would say addressed to the specific subjects of the agenda would be excessively presumptuous of me. You have heard Mr. Marsh discuss the very interesting history of the development of solid propellants from its early days to

the present. You all know that the solid propellant rocket has developed from a robust youngster not too different from those of Congreve and the ancient Chinese to a monster of power and performance which is beyond anything ever dreamed of as little as 25 years ago. In years past, a jest that one had as much chance of doing something as "going to the moon" was considered a prime example of low probability. In the relatively near future this jest will cease absolutely to be meaningful. The fact, however, that you people are, and in the future the bright youngsters of people present here today, youngsters such as Butch Roylance and Russel Couch for example, may be doing work which leads to human exploration of outer space is not the thing that should frighten us. What should be a major source of concern to us is the fact that Ivan Sergeevich and Nikolai Ivanovich are or will be doing the same thing and they may be a little bit ahead of us right now. Every incident we have involving these high-energy propellants which results in property damage, loss of production, or injury or death to persons serves to degrade our capability by a certain degree. We of the ASESB share with you a realization that complete absence of hazard is probably an unattainable utopia. We also realize that the tremendous technological advances of the past few years have not created a proportional increase in hazard. They have, however, created hazards which are different in degree and type from those we used to be concerned with. For example, just the enormous physical size of the units now being considered necessitates use of hoisting, handling, and conveying equipment of types which would not formerly have been approved for explosives operations. Due to program urgencies, the lack of specially-designed equipment, and other factors, it is frequently necessary to borrow or adapt items from other industries which can be used on emergency basis. Such equipment has sometimes, fortunately rarely, been a source of untoward incidents. We cannot honestly say that every propellant incident which has occurred could have been prevented. We must, however, strive to, as nearly as possible, eliminate all of those which could have been prevented. Now let us get on with the business at hand.

Captain Jenkins: It was impressed upon my mind recently how large a megaton is. In terms equivalent of TNT, if you were to take one megaton in TNT it would equal a string of boxcars fully loaded stretching here from Indian Head up to Philadelphia, a distance of about 200 miles. I recently read a book by H. E. Cook on the "Science of High Explosives". Possibly some of you are familiar with it. He mentioned early in the book how puny we are when it comes to the forces of nature. He mentioned the explosion in 1883 in Java when 1 to 3 cubic miles of dirt was pulverized and about 1 cubic mile of water was vaporized all in a matter of seconds. They had figured out that the amount of energy which it took to do that job would be the equivalent of 5,000 megatons. The Service representatives, Mr. Roylance, Mr. Endsley, and Mr. Jezek, briefly, are going to tell you some of the problems which they have had with respect to their own Services in the manufacture and development of these high-energy solid pro-

pellants. They will be followed by Mr. Brinkley from ORDSO. Mr. Roylance.

Mr. H. M. Roylance, Bureau of Ordnance, Asst. Chief Engineer-Munitions:
Gentlemen: I am not going to go into detail or list the incidents which have occurred at our activities during processing of high energy propellants. We have had our share and most of you know the basic facts. In looking over the ASESB Accident Summary No. 1, which was given to you with your copy of the agenda, I have noticed an interesting trend. I'm sure that this publication does not include all fires and explosions which occurred from 1946 to March of 1959, however, it is a good cross-section and can be used to indicate trends. You will notice that from 1946 through 1950 there were 5 or less accidents per year. In 1951 there was a decided jump to 15 accidents. I am not positive, but believe that it was about that time that we really began extensive work on the high-energy propellants. From 1951 through 1958 there were a total of 133 reported incidents. This is almost 17 per year which is about three every two months. You will also notice that the trend is downward with a drop from twenty in 1955 to seven in 1956, 14 in 1957, and 11 in 1958. We hope that this seminar, and others like it, will be instrumental in continuing the downward trend.

Mr. Gus S. Economy, Safety Engineer, Hill AFB, Utah:
Before I begin my summary of incidents, I will describe briefly the mission of the office I represent. I am from the Directorate of Airmunitions, Ogden Air Material Area, generally known as OOAMA. This Directorate is located at Hill AFB near Ogden, Utah, approximately 30 miles north of Salt Lake City. OOAMA serves as the ammunition center for the entire Air Force and provides the Air Force with technical and advisory support on all matters pertaining to explosive safety, including the manufacturing and handling of high-energy solid propellants. Because of our collateral responsibility in safety, we are vitally interested in the purpose of this seminar and wish to present a few representative incidents that occurred in plants manufacturing high-energy solid propellants. The data of these incidents were taken from reports received by our office. The dollar damage range of these incidents is from $50 to as high, in one case only, as $200,000. Fortunately there were no fatalities in these incidents. For purposes of continuity, these incidents are categorized into two groups: Group I. Incidents occurring during the manufacture of propellant mixtures. Group II. Incidents occurring during static firing and during other tests of solid propellant motors. A brief analysis of the probable causes of these incidents will be given. Group I. The majority of the incidents summarized in this group occurred during the mixing of ammonium nitrate propellants, and one incident involving ammonium perchlorate mixture. These incidents are listed as the probable causes:

a. Foreign material present in the propellant during mixing.

Two incidents of fire of a similar nature occurred in the Baker-Perkins mixer during the propellant mixing process. In both of these incidents, smoke was observed in the mixer bowl by operating personnel who had entered the cell to make the fourth and last oxidizer addition to the mix. In one case, investigation revealed small flat ribbons of steel in the propellant mix, which caused local hot spots. It is very probable that heat was generated by the friction of the steel ribbons caught between the mixer bowl and the blades. Similar ribbons of steel were also found on the canopy above the mixer. These steel ribbons were formed when holes were drilled in the canopy some weeks prior to the incident. The mixer had not been operated for approximately three weeks prior to this incident. When the mixer was started again, it is probable that the vibration of the machine caused these ribbons of steel to fall off the canopy into the bowl when it was open. The oxidizer propellant screens associated with this mixer were checked and found to be in good condition. This fact indicated that tramp metal was not likely to have been introduced during oxidizer additions. Other facets of this operation were investigated for conditions which might have contributed to this incident. Laboratory analysis for the presence of perchlorates were negative; mixer bowl and bearing temperatures were within operating requirements. In the second fire incident, granular steel particles were found in the propellant mix. Scrap marks were found in the bowl and on the blade tips of the mixer. Investigation indicated that maintenance work had been performed in the mixer bowl prior to the incident; therefore, it is very probable that the steel particles were left in the bowl during the maintenance work. This fire occurred during the mixing of the first propellant batch after the maintenance work was completed. Measurements taken of the clearances between the bowl and the mixer blades were found to be normal; therefore, eliminating the consideration of the possibility of the tips of the mixer blades coming in contact with the bowl.

b. Decomposition of ammonium dichromate.

Approximately 498 pounds of ammonium nitrate propellant was being mixed in an 100-gallon Baker-Perkins mixer. Operating personnel entered the mixing cell and added 99 pounds of oxidizer with ammonium dichromate. The cell was then evacuated and remote operation of the mixer was started. Immediately following the start-up of the mixer, the propellant ignited. Investigation of events prior to this incident indicated that the mixer bowl temperatures were 130°F, bearing temperatures were normal, mixer blade and bowl clearances were normal, no maintenance had been performed on the mixer prior to the incident, and no metal or other foreign material was found in the propellant mix. The packing was removed from all four of the mixer blade shafts and inspected. There was no evidence that the packing glands were the source of the fire or were even overheated. The four "Nylatron" throat bushings were inspected, and it was found that the left rear blade shaft throat bushing had been subjected to temperatures exceeding its melting point. The residue found on the bowl side of this bushing was analyzed in the laboratory. The analysis revealed the presence of ammonium nitrate and decomposed

ammonium dichromate. Although the cause of this fire was specifically determined, it is very possible that the friction of the mixing blades on large quantities of ammonium dichromate and oxidizer can produce local hot spots sufficient to decompose the ammonium dichromate and initiate a fire. The incidents just described involved propellants consisting of 80% ammonium nitrate, 15% co-polymer (binder), 3% ammonium dichromate, plus the remaining 2% of other additives.

c. Hot spots caused by high-frequency vibrations.

The following incident occurred during the processing of a perchlorate formulation: a fire occurred during the deaeration process of approximately 2000 pounds of a perchlorate formulation in the casting can. The casting can containing the propellant mix is a cylindrical-shaped vertical tank with a metal strap around the outside circumference of the can. The two ends of this metal strap are connected to air-activated vibrators. During the deaeration process of the propellant mix, the casting can is under vacuum and is vibrated. When the propellant ignited, the ensuing pressure build-up within the vessel caused the propellant to erupt out of the vessel. The polyethylene blow-out panel was burned out so that most of the flame was vented outside the mixer bay. This investigation indicated high and localized temperatures (hot spots) generated on the side of the casting can either by the friction between the vessel wall and the vibrator strap or by the high-frequency flexing of the strap. It is, therefore, very probable that the fire was caused by auto-ignition of the propellant, due to the localized hot spots. An experiment was conducted to simulate the conditions that caused the fire. The deaerator can was filled with cotton rags to the estimated propellant level at the time of the fire. The can was then vibrated; in a short period of time, the rags ignited. Temperatures at the local hot spots were estimated at approximately 700°F. A new vibrator strap has been designed of sufficient rigidity to prevent localized flexing. Tests conducted using the new vibrator straps indicated no serious localized heating. There were three other incidents in the Baker-Perkins mixer involving formulations of ammonium nitrate, in which the cause of the fire could not be determined. Approximately 470 pounds of propellant were in the mixer, all the additions of the raw materials had been made, and the mixing was proceeding according to operating procedures. During all three of these incidents, a muffled, rumbling noise was heard by the operating personnel, followed by the sound of the building siren that was actuated by the fire detection apparatus. The investigation following these fires revealed no mechanical defects in the mixer and no deviation from operating procedures; mixer shaft bearing and bowl temperatures were normal. Laboratory analysis did not indicate the presence of perchlorates in the propellant mixture nor chemical decomposition of the ammonium dichromate. Investigation of the oxidizer pulverizer screens showed no damage or tears; therefore, it is improbable that tramp metal or other foreign material was present in the oxidizer. After these incidents, wherein no cause could be determined, the following recommendations were adopted in order to improve the safety of the operation:

1. All mixers are to be inspected for loose or missing screws, bolts, and for other metal items that could inadvertently enter the mixer.

2. Every cell should be inspected for tramp metal and other foreign material and be removed from the building. This inspection will be performed before every batch mix.

3. Dummy propellant is to be run in all mixers to make certain they are in operating condition and that the mixer blades do not contact the mixer bowl.

4. The pulverizer screens where ammonium nitrate is ground are to be inspected twice during a shift for tears to prevent addition of foreign material to the propellant mix.

Group II incidents. This second portion of the report is a summary of the abnormal incidents which occurred during static fire testing or environmental testing. The type propellants used were formulations of cast ammonium perchlorate. The motor cases were hydro tested at 2,250 psi. These incidents are grouped according to the type of failure that occurred and the probable cause of the incident with a brief description of the propellant formulation.

A. Nozzle Ejections. Three motors ejected the nozzles when the safety release rings failed at pressures of 1,500 - 1,600 psi. In each case the failure was attributed to an increase in the burning area of the propellant grain. This was caused by poor propellant-to-liner bonding. Ejections occurred during the first 1/2 second after ignition. The propellant consisted of a polyurethane fuel containing 68% A.P. and 12% aluminum powder. Two additional motors using the same propellant ejected nozzles at 1,330 psi. Ejections occurred at ignition, and this is attributed to fatigue failure of the release ring. All grains were tubular, internal and end-burning.

B. Gas Leakage. One motor, using polyurethane base propellant containing 70% ammonium perchlorate, 5% aluminum, and 5% Boron burned through and completely eroded the igniter plug. The igniters are installed in the forward head with an insulated center post type electrode. Gas leakage at the electrode is attributed to improper installation during igniter assembly. This unit contained a slotted tube-type configuration with burning surfaces being internal. Pressure plug gas leakage also caused another unit, with the same configuration, to burn away 50% of the forward head. The propellant used in this unit was a polybutadiene-acrylic acid binder containing 75% A. P. and 20% aluminum. Exact cause of this failure is unknown.

C. Case ruptures. Three units ejected both nozzles and a 2½ inch section from the aft end of the case. These units contained end-burning grains cast from a polyurethane-based propellant containing 68% A. P. and 12% aluminum. In each case, the burning time before case rupture was 5 - 7 seconds and burst pressures were from 1,800 to 1,900 psi. These units were being used for case liner evaluation tests. The cause of excessive pressure was attributed to propellant-to-grain bond failure resulting in an increased burning area. Another case rupture was experienced with a polybutadiene acrylic acid-based propellant containing 75% A. P., 16% aluminum, and 4% copper chromite. Case rupture occurred at 2,400 psi approximately .55 seconds after ignition. Propellant-to-case wall bond failure, resulting in approximately 50% increase in burning surface is believed to have caused the pressure increase. The next two incidents that I shall discuss involved extruded ammonium nitrate propellant grains. A motor mounted on the test stand was fired with an experimental 1,200 gram igniter. At about 150 milliseconds after the motor fired, the head came off the motor, and the motor base pulled loose from the stand. A portion of the motor liner remained in the case and continued to burn. After approximately 15 seconds, most of the propellant which was on fire burned out. There were two probable causes. The igniter blast threw igniter material like a shot-gun blast, causing (1) propellant break-up due to the shock of ignition, or (2) extremely high burning rate of the igniter. Pressure readings taken from instrument traces indicated a large pressure drop from fore to aft of motor, indicating a large area of propellant burning in the forward end of the motor. This motor contained approxmately 2,940 pounds of ammonium nitrate formulation. The igniter contained potassium perchlorate with the following additions: aluminum, zirconium, and nickel. It is possible that this igniter with 1,200 grams in one sack, intended to "shot gun blast" the propellant for ignition, is unsatisfactory. Further use of this type igniter was discontinued. The other incident occurred with a 124-pound extruded ammonium nitrate propellant grain supported in the motor case by rubber pads. The motor was removed from the hot conditioning cell of 175° F, and placed in the vibrating box for testing up to 5 g's. The motor case was positioned in a parallel plane with the direction of motions of the vibrating cell. Approximately 15 minutes after the vibration started, an explosion occurred. The frangible wall of the test cell was completely blown out. The motor case ruptured on its longitudinal axis, and broken propellant grain was found scattered approximately 90 - 100 feet away from the test cell.

Probable cause: The vibrations caused the grain to shift in the case, producing local hot spots between the grain and the motor case. The breaking up and wide scattering of the propellant grain substantiates this conclusion. There was no igniter installed

in this motor.

Mr. William Haite, Chief, Process Development Department, Redstone Division, Thiokol Chemical Corporation: You mentioned the fire, specifically an instance which happened in the Baker-Perkins mixer. Was this in the mixer?

Mr. Economy: Perhaps I should clarify this further. The fire occurred in the propellant mix which was in the Baker-Perkins mixer. The composition was ammonium nitrate propellant.

Mr. Haite: What was the cause?

Mr. Economy: These particular fires, they believe, were caused by local hot spots due to the metal particles found in the propellant mixture and they believed the particles were caught between the mixer bowl and the blades during the time the mixer blades were in rotation. They found scrape marks which would align between the blades and the mixer bowl. I have more details I can furnish. I have them at the hotel.

Mr. Louis Jezek, Safety Engineer, Office Chief of Ordnance: Since January 1946, or just about the time when some of us were returning to civilian life from World War II, the Army Ordnance Corps has experienced 14 major incidents while manufacturing or testing propellants for large-size rockets or missiles. These 14 major incidents caused 10 people to be injured, 6 fatalities, and property damage totaling many thousands of dollars. Since 1956, however, it is encouraging to note that only one fatal accident has been reported as a result of rocket propellant manufacturing. This accident occurred on a pilot line and involved an experimental type of propellant. Several of these major incidents were published in the form of Army Ordnance Safety Abstract Reports. For the benefit of the representatives who are here from private industry and may not be familiar with safety abstract reports, copies will be available after the next break. The supply of these reports is limited and it would be appreciated if only one copy for each firm is taken. The Army, Navy and Air Force are on the distribution list to receive these reports, and copies should be available at their home stations. Mr. Harry Brinkley from the Army Ordnance Field Safety Office, will now show you slides and he will discuss some of the incidents involving rocket propellants that have occurred at Army Ordnance installations.

Mr. Harry L. Brinkley, Supervisory Safety Engineer, Ordnance Field Safety Office: Rocket Extrusion Press Incidents. Intelligent safety work in explosives and propellants requires a knowledge of what to expect of them under various conditions. Unfortunately, some of this experience is acquired through the medium of accidents which involve the loss of life and property. Therefore, safety precautions are usually born in an accident.

During the next several minutes, I will give you some lessons learned from explosives incidents involving rocket propellant extrusion presses, without the necessity and obvious disadvantage of exposing your installation and you to a serious incident. Seven explosive incidents involving rocket presses have occurred at Ordnance installations during the past eight years. I appreciate this opportunity of describing several of these incidents which I hope will assist you in obtaining a better understanding of the potential hazards when extruding rocket propellants. First, I want to state that there has not been a single injury resulting from the rocket press accidents, although the loss of property and equipment was high in several instances. This is a tribute to the design and safety engineers who designed the R. D. Wood type rocket presses and the facilities which have provided positive personnel protection to the operating personnel. The first accident I would like to describe is an explosion and fire which occurred 6 December 1951. JPN, a double-base solventless propellant containing 51% nitrocellulose and 43% nitroglycerin, was being extruded at one-half inch per minute. The press contained a heel of propellant (which was in place overnight) plus 1 carpet roll, or a total of 80 pounds of propellant. The press had been down 16 hours. A normal vacuum (10 mm of mercury) was drawn on the press basket, and the ram was started forward. The pressure built up rapidly, and fell rapidly, and started up again when the shot occurred. The SOP had been followed, and the press was in good mechanical condition. The pressure was 2100 psi at the time of the explosion. Examination of the vacuum flaps after the explosion showed perforations in the flaps with the edges of the perforations extended out from the ram head. These perforations were apparently caused by the vacuum plugs being forced through the flaps. This indicated that the detonation started in the vacuum system and propagated to the press basket. A large percentage of the carpet roll and powder heel was found scattered in the surrounding area. Fire from the explosion destroyed the wooden section of the press bay. The damage was estimated at $17,000. The recommendations made were to:

1. Clean the vacuum system every 30 days with acetone.

2. Replace copper tubing in the vacuum system with rubber tubing.

3. Maintenance checks to be made every 500 extrusions, or every 30 days, whichever occurs first.

4. All hot water heaters on circulating systems to be shut off if the press is to be down for more than 8 hours.

The second incident to be described involving the conventional 15-inch R. D. Wood type solventless extrusion presses occurred on 21 November 1956. Personnel were conducting a "waxing out" operation. The press had operated normally as evidenced by 150 completed extrusions. The press had been overstroked and loaded with 38 pounds of candelilla wax and the normal waxing out process had begun. The press had passed through approach and consolidation speed, and had entered extrusion

speed reaching approximately 1200 psi pressure when the explosion occurred. There was approximately 30 pounds of M16 propellant in the press at time of explosion. The shear plate did not function as designed. The estimated damage from the explosion and fire was $38,000. Vacuum system is shut off during waxing out operation. Investigation revealed the following as the most probable causes of the explosion:

1. Adiabatic compression of air entrapped in the wax or in the basket of the press may have produced a "hot spot" in the wax or at the interface between the wax and propellant.

2. Propellant may have escaped past the approach seal ring into the cavity between the approach and the basket of the press during previous extrusion, and may have been initiated by friction or some other means.

3. The die plate assembly which had been subjected to a previous explosion may have been overstressed during that explosion, and upon repeated application of pressure over a period of time, may have failed at one or more points around its periphery.

Recommendations for correction and prevention include:

1. Magnaflux or equal any critical part of a press that has been subjected to the force of a major explosion.

2. Wax used in the waxing out operation not be reused.

3. The approach seal ring be redesigned to insure that it remains in place to prevent escape of propellant into the cavity between the approach and the basket during normal operation.

4. Wax be cast in cylindrical disks of such diameter as to afford the minimum acceptable clearances, and that disks of wax do not contain holes or air pockets.

The third and final selected incident occurred 23 March 1959 during a propellant extrusion operation involving approximately 800 pounds propellant. Propellant was being extruded from a 15-inch R. D. Wood type press into a Ramold being conducted in connection with an industrial engineering project. The press had been "heeled in" by 1000 hours by leaving the equivalent of 7 carpet rolls (266 pounds) in the press as a heel for the Nike grain. At approximately 1620 hours, the operators had completed four extrusions of 3 carpet rolls each, and then loaded the press with 2 carpet rolls in order to obtain the desired grain weight. The engineers entered the control room and started the press. The press entered its cycle and went through the consolidation speed cycle, entered extruding speed, and reached approximately 2250 pounds of pressure, with 2 inches of propellant to be extruded, when the explosion occurred at approximately 1632 hours. Only a small amount

of the involved propellant (800 pounds) fired within the mechanism. The hydraulic oil fired on rupture of hydraulic lines. The estimated damage from the explosion and fire was $122,600 to the frame structure and equipment. Investigation indicated the explosion initiated in the die assembly. The probable cause of the explosion was due to one or a combination of the following, in which items 1 and 2 appear to be the most probable.

1. Frictional heat or pinching of propellant in the die assembly resulting from movement of one or more shoes of the jack screw assemblies.

2. Sheared tension bolts — propellant may have escaped through opening.

3. Mechanical failure of the press.

4. Misalignment of the Ramold press assembly.

5. Metal fatigue.

6. Foreign material.

7. Ignition of propellant "flash" due to metal-to-metal contact.

Recommendations for correction and prevention include:

1. The die stake adapter and die approach plate will be redesigned and built to support the stake nose piece integrally with the die, eliminating the three jack screws.

2. Present type hydraulic oils will be replaced with oils of a higher ignition point, or synthetic oils of a non-combustible type.

3. Saddle will be installed to give presses more base support.

4. Hydraulic piping to the press will be provided with either an expansion loop or flexible base to prevent line breakage.

5. All equipment not immediately needed for the operation will be kept out of the area in front of the press.

Horizontal 15-inch R. D. Wood type press accidents were believed caused by one or a combination of the following:

1. Metal-to-metal contact due to thin or no flash of propellant between basket wall of press and ram head. Tolerances were zero at certain points.

2. Adiabatic compression. Air trapped in propellant or press not removed by vacuum pumps and the air under ram pressure heated by compression, the heat causing nitroglycerin vapors to be detonated by

adiabatic compression.

3. Metal in carpet rolls.

4. Nitroglycerin condensate in the vacuum system.

5. Metal fatigue.

6. Mechanical failure in press operation.

7. Personnel failure.

8. Frictional heat.

A study and evaluation of rocket propellant press incidents reveals the following similar characteristics:

1. No damage to adjacent facilities.

2. No injuries to assigned personnel.

3. The hydraulic line broke or ruptured.

4. The press moved back and off the cradles.

5. The die and holder were projected from the press.

6. No definite cause determined; however, the following explosions recorded could have resulted from the condition listed:

Incident of 6 December 1951 - nitroglycerin in vacuum line.
Incident of 19 September 1953 - nitroglycerin condensation in die seal ring.
Incident of 6 September 1955 - unknown.
Incident of 12 October 1955 - unknown.
Incident of 1 April 1953 - ram head unscrewed.
Incident of 21 November 1956 - mechanical failure.
Incident of 23 March 1959 - frictional heat.

7. Safety factors which had been incorporated in the design and construction of the press house functioned as intended, confining the damage to the frame portion of the building.

8. Safety factors incorporated in the design and construction of the press functioned as intended; i.e., shear ring sheared except in the incident of 21 November 1956, which was due to mechanical failure of the press, based on previous maintenance records.

9. There was no evidence that standing operating procedures were violated.

Captain Jenkins: It is good to "air some of your own dirty linen" and especially for the Ordnance Corps to air theirs in a vivid manner. You people felt you had most of your trouble in your presses and in these timely recommendations you have given, and I hope that by "airing this linen" we can "keep some of our own clean". Mr. Millin of the Minnesota Mining and Manufacturing Company, also had some "dirty clothes" he was going to give us. We will hold that until after lunch. Wouldn't it be better to go over on time, Captain Atkins? We have some questions here, but I think what we will do is this. If any of you people have particular questions to ask and inquire about, assemble here about ten minutes to one. Can you be back, Mr. Brinkley, by ten minutes to one? Ask him any particular questions about these incidents which he has mentioned, and that will give you other gentlemen a chance to ask questions. Mr. Millan, would that be all right for you to take these up after lunch? Thank you very much. For those of you who have a particular interest in this, come back about ten minutes to one and we will start the ball rolling again. Thank you.

(Lunch period)

Mr. Haite: Solid propellants are basically high-energy mixtures of a fuel and oxidizer which, after certain process steps, are a solid mass possessing sufficient physical strength and mechanical properties consistent with the manner in which they are used. Because of their composition, combustion progresses in the absence of air or other externally supplied oxidizer. The fuel and oxidizer may be chemically bound or in solution, as in single and double base propellants, or they may be chemically separate entities consisting of a generally elastomeric fuel and one or more crystalline inorganic salts. Other ingredients are normally added to impart and control desired physical and ballistic characteristics to the propellant. The particular chemical and physical differences of the propellants being developed and manufactured require a variety of process methods. These methods can be catalogued into five major functional processes — raw material preparation, mixing, deaeration, casting, and curing. A discussion of the application of these processes in propellant manufacture follows:

Raw Material Preparation.

Ingredients which are to be mixed in their natural forms may require treatment to control the amount of moisture or gas present, that is residual in manufacture or absorbed during storage. Other ingredients, primarily crystalline oxidizers, may require drying, screening, blending, and particle size reduction. Drying is accomplished in hot-air circulating ovens or by using air transfer at 140°F to 200°F. High throughput gyratory or vibrating screens are used to remove tramp metal present in the unground oxidizer. Close sized fractions of ground and unground oxidizer are obtained with mechanical or air classifiers. Higher performance, especially in the composites, usually is obtained by increasing the solids content of the formulation, thus adversely affecting the processability and physical properties. These characteristics can be optimized by proper selection of the close

sized fractions, without detriment to the ballistic properties. Blending of the oxidizer prior to addition into the mixer is not a necessity, but some manufacturers find that it simplifies handling and control problems. If ground and unground fractions are blended, a "riffle" blender is recommended. Local and process conditions frequently necessitate incorporating a small percentage of a free-flowing agent. This is readily accomplished in a double cone or other mechanical rotating blender. Air impact or hammer mills are now available to obtain ground oxidizer in specified particle size ranges and ultimate particle sizes. The micromerograph has proven to be the most effective tool to measure the actual distribution obtained.

Mixing.

No matter what propellant is manufactured, ingredients must necessarily be mixed to provide a homogeneous mass. A number of high-intensity mixers are available for this operation. Double blade horizontal mixers of either the Sigma or Dispersion type are probably in most common use. Modified blade designs are available to suit the user's fancy. In some propellants, the order of addition of materials to the mixer is critical, but basically, the methods used fall into three groups: (1) charge all of the major ingredients into the mixer before the start of the mixing cycle; (2) add all or the major portion of the liquid fraction or resin to be melted, and then add the other components at intervals throughout the cycle with the blades either turning or stationary; (3) charge all of the major dry ingredients into the mixer and feed the liquid components with the mixer in operation. In some instances, either method may prove satisfactory and the choice depends on the particular mechanical setup. Continuous mixing, particularly of the composite propellants, is now in a rather advanced state of development and can be accomplished with one of several pieces of equipment available. Utilization of continuous mixing depends on the precision of feeding equipment and the development of controllers and analytical techniques and instruments to prove that the continuous discharge is homogeneous and has the proper composition.

Deaeration.

The removal of air and entrapped gases is important for the manufacture of propellant with reproducible characteristics, either on a batch or continuous basis. Vacuum mixing or vacuum casting or a combination of both is used to provide void-free propellant. Batch deaeration is accomplished by forcing the propellant through small holes or thin slits into an evacuated chamber and is an effective means of removing air in castable propellants. This technique is normally referred to as the "slit deaeration" process. Slit deaeration eliminates the need for more expensive vacuum mixers and can be readily integrated into a continuous deaeration system.

Casting.

Castable propellants, whether case-bonded or not, can be loaded directly into the motor case or grain mold by either a pressure or vacuum casting technique. Pressure casting requires pressure tanks from which the

deaerated propellant is forced through one or more bayonets into the desired container. During casting, quality of propellant is maintained by keeping the end of the bayonet beneath the propellant surface. In some instances, the propellant is forced into the container from the bottom. Vibration is generally applied to the system to improve flow and maintain a consistent level as the container is filled.

Curing.

Solidification of the propellant from a heavy mastic or fluid form is generally designated as "curing". Depending upon the propellant, this operation may consist of cooling of the mixture or applying heat to maintain a temperature at which polymerization or gelation of the binder takes place. One widely-used method to obtain cure is the storage of the loaded motors or grain molds in an oven heated by hot air forced through a heat exchanger. Where better control of temperature is desired, or where it is necessary to cure the propellant in increments, the use of water baths or electric blankets is more desirable. The large rocket motors now in development frequently have faults in the propellant mass which can be attributed to the contraction of the mass in accordance with its thermal coefficient of expansion. Sound castings can be better realized by using electric blankets to obtain zonal curing. Each portion can then be allowed to cool to a nominal temperature prior to cure of subsequent zones. This eliminates the effect of the contraction of the entire mass. As the state-of-the-art of propellant processing advances, the requirements for large quantity production of a given item will undoubtedly be met by a completely continuous system for propellant manufacture. Controls, feeders, and analytical methods will eventually be improved to make this a reality. At that time, and even now, where the double base propellants are concerned, the batch operations described herein may be discarded.

Captain Jenkins: Thank you very much, Mr. Haite, for this good introductory here. We will hear more from you later, I assume. Mr. Cutler is going to discuss the hazard characteristics of oxidizers and metal powders and fire control measures. Mr. Cutler is from the Department of the Army Chemical Corps at Edgewood, Maryland.

Mr. Milton Cutler, U. S. Army Chemical Warfare Laboratories: Gentlemen, I should like to take this opportunity to convey to you on behalf of the Chemical Corps, our sincere appreciation for having been asked to participate in this program. The CmlC is extremely interested in the area of pyrotechnics as propellants and fuels, and feels that it has much to contribute and much to learn by engaging in discussions such as these. This is especially true in this specific instance, since the conferees here represent the "cream" of the knowledge and experience in the propellant field. The Chemical Corps has had wide experience in the propellant field. It has had wide experience in pyrotechnics. Although our requirements are for lower energy materials, I think that it is safe to say that any differences in technical activity or requirements are differences in degree rather than in kind. We, too, have handling problems with oxidants and reductants involving not only the handling of these materials individually, but also in combining these potentially hazardous chemicals into pyrotechnic mixtures. Most of our mixtures are

manufactured and used in the dry state. Obviously, our operations may be as hazardous, if not more so, than yours despite the fact that your mixtures are employed as high-energy propellants. For this reason, we are attempting to get away from the dry pyrotechnic mixture in favor of the so-called "wet" or plasticized mixture. Much work has been done in this area over the last few years, and some of our pyrotechnic fillings have already been converted. However, much work remains to be done. When this conversion has been accomplished, our problems should be identical with yours. Before I discuss specific problems with respect to the handling of metal powder and oxidants, I should like to present briefly the types of material in which the Chemical Corps is interested, as well as the manufacturing operations incident to the preparation of CmlC pyrotechnic mixtures. We handle essentially 4 types of chemical ingredients for pyrotechnic mixtures: (a) oxidizing agents - between 40% and 85% of every CmlC pyrotechnic composition consists of an oxidizing agent. Potassium chlorate, an extremely hazardous material as you well know, is one of the major ingredients in colored smoke as well as in various igniter compositions. Barium nitrate is the oxidizing agent employed in incendiary compositions. Ammonium nitrate is the major constituent of our fuel blocks. These oxidizing agents are handled in huge quantities (hundreds of tons per day), especially during times of emergency. Of course, the quantities of material being handled today are considerably less.
(b) reducing agents - a variety of reducing agents in virtually the same quantities as described above are used as fuels in the various CmlC pyrotechnic compositions. Among these are sulfur, sucrose, charcoal, and many finely divided metallic powders such as titanium, zirconium, and aluminum. The non-metallic reducing agents are commonly used in colored smoke and various first fire compositions. The metal powders are commonly used in the manufacture of first fire, delay compositions, and igniters. Aluminum powder is a major ingredient of CmlC incendiary compositions.
(c) inhibitors - all pyrotechnic compositions requiring a constant, or predetermined burning rate must contain an inhibitor to achieve the desired performance characteristics. The most common inhibitors employed in these mixtures are magnesium carbonate, zinc carbonate, and sodium bicarbonate. These chemicals are quite safe to handle under any conditions.
(d) anti-agglomerates - most pyrotechnic compositions require the presence of an anti-agglomerate to improve their free-flowing properties. Two of the anti-agglomerates in common use are tricalcium phosphate and magnesium oxide. These materials are non-hazardous under all conditions. So much for the broad classes of materials which are handled in the CmlC pyrotechnics program. Although the ones specifically described are only few in number, they are representative of the many, many chemicals actually employed. The operations for manufacturing pyrotechnic mixtures of various types are quite similar to the ones employed in the solid propellant industry. Broadly speaking, they are as follows:

a. Drying. Usually the non-metallic ingredients of any given pyrotechnic mixture must be dried to remove excess moisture. This operation is usually required with the oxidizing agents since these materials are, for the most part, hygroscopic to some degree.
Drying is accomplished in tray dryers, or rotary dryers,

depending upon the quantities of material used. This operation is normally conducted at fairly low temperature (up to 140°F) and is not considered unusually hazardous as long as the oxidizing agent is free of dirt, oil and other gross impurities. Frequently a pyrotechnic mixture which has been manufactured wet must be dried in order to drive off the liquid medium. These mixtures are normally first fires and delay compositions which are extremely sensitive to ignition. The drying operation is accomplished in a tray dryer in which the circulating air is usually maintained at a maximum temperature of 110° F. Very careful handling procedures and maximum protection devices are employed in this operation in order to minimize the possibility of an incident.

b. Grinding and Micropulverizing. Metallic powders are normally procured in the desired particle size and are therefore not ground in CmlC facilities. However, nearly all of the oxidizing agents must be ground prior to their incorporation into pyrotechnic mixtures. Two types of grinding equipment are employed: the Steadman ring-roll crusher and the Fitzpatrick Comminuter, Model D. Both machines are made of steel and contain no special safety devices other than electrical grounding to eliminate static buildup. Grinding operations are remotely controlled and protection to the operators is afforded by the necessary reinforced concrete barricades. Huge tonnages of potassium chlorate, ammonium nitrate and barium nitrate have been micropulverized over the years. I recall one such sustained run which occurred in 1944 at the Huntsville Arsenal where several hundred tons of potassium chlorate were ground on a 3 shift basis over a period of several months without a single incident. It is our opinion that the grinding of these oxidizing agents is relatively non-hazardous provided the material is clean and free from dirt, oil, metal scrap, paper, and other types of impurities.

c. Mixing and Blending. After the drying and grinding operations, the components of a pyrotechnic mixture must be mixed. If the mixture is dry, a double cone blender or a tilting and tumbling barrel are normally employed. Stigma blade, ribbon, edge runner, or other agitator or paddle type mixers are never employed in the manufacture of a dry pyrotechnic mixture. The mixing equipment which is employed is constructed of copper or bronze and extreme safety precautions are taken. Although batch operations are used, all equipment is grounded, barricaded, and remotely controlled. Containers are usually made of plastic impregnated fiber to avoid metal-to-metal contact. We have never had an incident during the actual mixing cycle. Those incidents which have occurred have taken place when personnel were either charging or discharging the mixer. Although we have considered modifying the mixing procedure to achieve a continuous mixing process with complete automation as an ultimate goal, this yet remains to be realized. As I indicated previously some of our more hazardous pyrotechnic mixtures are manufactured in the wet state. A volatile liquid such as water or acetone is used in some, while a liquid monomer is used in those cases where a truly

plasticized mixture is desired. First fire and delay compositions are normally not required in large quantities. These mixtures are blended in small Hobard mixers similar to the Sunbeam Mixmaster. Frequently when very small quantities are required, a hand operation is employed. This is normally conducted in copper-lined buckets using wooden paddles. Although extreme precautions are taken to avoid incidents, they have occurred in the past. It is our belief that these were caused by friction of the paddle on a small, dry quantity of mix which may have been present in the equipment.

d. Research and Development Studies. Research and development studies on plasticized colored smoke mixtures have been conducted. Indications are that the Hobart vertical mixer and the ribbon-type mixer can be successfully employed provided precautions are taken to eliminate the presence of dried material. No incidents have yet occurred in this program. It remains to be seen whether successful operation from the safety standpoint will be achieved in large-scale production. In this connection, extra precautions must be observed to prevent frictional heat in bearings, and packing glands. Clearance between the agitator and the mixer wall is also critical and should be carefully watched to avoid friction.

e. Granulating. Most first fire and delay compositions must be granulated and dried prior to loading. As soon as the wet mixture has been prepared, it is transferred to a Stokes oscillating granulator. Many incidents have occurred in this operation since all of the factors favorable to ignition of the mixture are present. As a result, minimum quantities of mix are granulated in any given batch and the operation is remotely controlled to avoid injury to personnel.

f. Filling and Consolidation. When the pyrotechnic mixture has been prepared, it is filled and consolidated into the appropriate container (munition, delay housing, canister, etc.). The filling operation is accomplished by one of three methods depending upon the sensitivity of the mixture (force feed, gravity flow from the hopper, and hand filling). Many incidents have occurred in the force feed operation, especially where the auger-type Stokes-Smith filling machine was used. This equipment consists of a hopper containing the mixture from which an auger delivers it to the container. Fires have occurred in the housing surrounding the auger. Investigation showed that these fires were primarily caused by the wearing away of the auger flights thus permitting too large a clearance between the auger and the housing. This caused a gradual buildup of caked mix on the inside wall of the housing which became excessively heated by auger friction until the ignition temperature of the mixture was reached. The problem was solved by frequent replacement of augers as well as by the use of additional filling machines as standby equipment. A procedure was also instituted whereby, when the housing area of a filling machine in operation became hot, the equipment was shut down and a standby filling machine was activated. Successful operations were achieved and no further incidents occurred through the employment of these techniques.

The gravity flow equipment consisted of a large hopper with a valve at the bottom. The mixture is delivered to the appropriate container by merely opening and closing the valve. No incidents have ever occurred with this equipment. Hand filling is normally employed with mixtures of extreme sensitivity such as first fires and delay compositions. The most important factor in preventing an incident is proper training of the operating personnel. Very few incidents have occurred in this operation. Consolidation of the mixture is normally accomplished through the employment of a hydraulic or pneumatic press. The length of stroke, consolidation pressure, and speed of stroke are largely dependent upon the munition being loaded. Many incidents have arisen in the pressing operation. By reducing ram speed to a minimum consistent with the production schedule, by carefully assuring proper indexing of the mold under the ram tip, and by carefully controlling the clearance between the ram tip and the container walls (a minimum of .060" on a 4"-to-5" diameter is required) incidents at the press have been virtually eliminated.

g. Pelleting. Many first fire and delay compositions are pelleted in a Stokes pelleting press prior to their incorporation into the end items. The pelleting operation is no different from similar operation conducted in the explosive industry. Although incidents frequently occur here, personnel are completely protected since the operation is completely remote and since the quantity of material is kept to a minimum insofar as possible.

h. Vacuum Cleaning. At one time all spills of pyrotechnic mixture around the equipment and in the operating cubicles were removed by the employment of a Spencer Vacuum system. This proved to be highly unfeasible because of the frequent incidents which occurred. This was traced to a buildup of static electricity in the particles of mix passing through the vacuum lines at high speed. The problem was solved through the elimination of the vacuum systems. The procedure currently employed is merely to sweep up the spills as they occur and to wash down the equipment and operating areas at regular intervals.

Now that we have discussed the materials and the manufacturing operations associated with pyrotechnic mixtures, I should like to discuss some of the general hazard conditions favorable to causing an incident. As you have seen, our materials may exist in dust form as well as in bulk.

a. Dust. I think that it is safe to say that all combustible dust will explode under the proper conditions and that some dusts will explode more easily than others. Let us consider some of the more important conditions favorable to the explosion of a dust:

(1) Combustible Material. Obviously one must start out with a combustible material. All oxidizable materials fall into this category. This includes the metal powders as well as many chemical compounds which are normally used in fuels as reducing agents. Although carbon is frequently used as the

reducing agent it is curious that a high grade carbon such as a pure form of lamp black or graphite cannot be made to explode. Those forms of carbon which explode readily usually contain combustible impurities.

(2) Particle Size. The smaller the particle size of the material the more hazardous the material and the easier it is to induce the particle size above which it is different to induce explosion. Particle size less than twenty-mesh can be made to explode more and more easily as the particle size is reduced.

(3) Concentration. A favorable concentration of combustible material suspended in the atmosphere must be present in order to induce explosion. Approximately 5 million particles per cubic foot are considered to be the minimum. When one considers that there are 1 million dust particles per cubic foot in the atmosphere of this room, one realizes that 5 times that many particles per unit volume of atmosphere represent a very low concentration. Of course, the particle size and the chemical reactivity of the material are important factors.

(4) Atmosphere. A favorable atmosphere around the dust particle must be present. This is normally always the case since oxygen will support combustion. The obvious conclusion, therefore, for reducing the explosibility of a dust is to introduce an inert gas to replace the air: one which will not support combustion. One must proceed very cautiously here. For example, carbon dioxide is normally considered to be a reasonably inert gas. Yet, magnesium and aluminum powder react violently with carbon dioxide. Similarly, freon as well as nitrogen are conducive to the formation of an extremely favorable explosive atmosphere with certain metal powders.

(5) Ignition Source. In order to explode a dust a source of heat is normally required. This heat source can easily be produced by a static discharge, frictional spark, or frictional heat. Think of some of the items of equipment which we have discussed so far today, and you will realize that, unless the proper precautions are taken, all of the equipment is perfectly capable of producing the required heat sources.

(6) Ignition Temperature. Different materials have different ignition temperatures and these vary widely depending upon the chemistry of the material involved. Most of the material commonly in use in the pyrotechnic and propellants industry have been described in the literature with their ignition temperatures and I will not dwell on this. Suffice it to say that the lower the ignition temperature, the easier the ignition and subsequent explosion.

(7) Shape, Surface Structure, Surface Area. These are important considerations in considering the explosive properties of dust. This is especially true in the case of metal powders. For example, aluminum particles can be either spherical, granular, or flaked depending upon the process of manufacturing. Since the flaked aluminum powder has the largest surface area,

it can be ignited much more readily than the other two forms. Similarly the atomized form is the most difficult of the three to ignite. This is the case even when the particle size of the three forms of aluminum powder being compared is the same. I am reminded of a number of serious explosions which took place in 1942 in our incendiary manufacturing plants. During a single week the incendiary plants at the Huntsville Arsenal, Alabama, the National Fireworks Plant at West Hanover, Massachusetts, and 2 or 3 others were destroyed by fire and explosions. Investigation showed that the primary cause was the presence of flaked aluminum in the incendiary mixture. Accordingly, the specifications were modified to substitute atomized aluminum in place of flaked aluminum. As a result, the number of incidents subsequently decreased to a negligible amount.

(8) Chemical reactivity. Some materials are much more chemically reactive than others. For example, aluminum dust can be handled with a greater degree of safety than zirconium dust. Finely divided zirconium, when dry, is pyrophoric and must be treated accordingly.

b. Bulk.

Although bulk materials are normally less hazardous than the same material in dust form, the same conditions favorable to ignition and explosion of dust is applicable to bulk. For example, we still need a combustible material or mixture, a source of heat, a favorable atmosphere, etc. This is primarily due to the fact that even in bulk form a given material will always have a minute layer of dust at the surface. Let us now consider the hazards involved in the handling of metal powder. Practically all metal powders oxidize readily. Therefore, they can be considered to be combustible materials. Therefore, they can be ignited and exploded under favorable conditions to the explosion. What are these favorable conditions? They are identical to the ones which we have just discussed. Similarly the conditions necessary for the ignition of bulk metal powder are, again, the same as those already discussed. There is one fact which should be mentioned here: the rapid reaction between liquid water and certain metal powders. Aluminum powder and magnesium powder, particularly, react vigorously with water. If a drop of water should fall into a pyrotechnic mixture containing a reactive metal powder and the mixture is subsequently consolidated or cured into a cake or grain, an explosion may result. The reaction between the metal and the water is exothermic and produces hydrogen as a decomposition product. Some of the conditions favorable to an explosion are thus present: heat source, hydrogen gas, high degree of confinement, finely divided particles etc. In our loading of screening smoke munitions where the mixture contains atomized aluminum, we must be very careful to prevent water from dropping into the mix from overhead pipes and deluge systems. Accordingly, all overhead piping is insulated to prevent condensation on the outside and all sprinklers

and deluge nozzles are offset. One of the most hazardous materials in bulk form is dry zirconium powder. For this reason, zirconium is handled wet whenever possible. Fortunately, zirconium happens to be one of those metal powders which does not react with water. The problems associated with the handling of oxidizing agents are quite similar to those described above. Oxidizing agents such as chlorates and perchlorates which are considered to be extremely reactive chemically, are quite safe to handle as long as the material is free from reducing impurities. Not only is this the case in the bulk form, but this is also true when the material is present as an airborne dust. The Bureau of Mines has reported that oxidizing agents of this category in dust form could not be exploded even when relatively large quantities of energy were expended. Chemical Corps experience in the handling of oxidizing agents per se during the past 18 years has certainly confirmed this. At no time has there been any report of an incident with potassium chlorate, barium nitrate, or ammonium nitrate, in their pure form. One of the most important considerations in the handling of chlorates is the formation of acid either by hydrolysis of the chlorate in the presence of moisture, or as a result of the decomposition of one of the ingredients in the pyrotechnic mixture. Potassium chlorate hydrolyzes to form chloric acid in the presence of moisture. Acids react violently with strong oxidizing agents such as potassium chlorate. Therefore, every precaution must be taken to ensure that the presence of moisture in the chlorate is minimized during all of the phases of manufacturing. Potassium perchlorate does not hydrolyze as readily, and therefore represents less of a hazard problem. However, both the chlorate as well as perchlorate are very powerful oxidizing agents and should, therefore, be treated with the utmost respect. The decomposition of an acid-forming constituent in admixture with potassium chlorate is well illustrated by Chemical Corps experience in the manufacturing of yellow smoke mix. The yellow dye, until fairly recently, was auramine hydrochloride. The oxidizing agent is potassium chlorate. In the presence of moisture, auramine hydrochloride decomposes to liberate free hydrochloric acid which is capable of reacting violently with potassium chlorate. As a result, Chemical Corps experience in the manufacture of yellow smoke mix during World War II was hair-raising. For example, at the Huntsville Arsenal, we had two filling plants located side-by-side. As soon as one plant "went up", the personnel were moved to the second plant. At about the time that the first plant was cleaned up, the second plant "took off" and the personnel were moved back to the first plant. Manufacturing operations were continued for several years in this manner despite the fact that there were times when we averaged 14 fires per 24-hour day. In order to resolve any future recurrence such as this, a program was recently completed in which the auramine hydrochloride was replaced by a more stable, non-acid-forming dye of the anthraquinone type. There has been no reported incident traceable to the dye since that time. I should like to again emphasize the fact that acid is extremely hazardous in combination with chlorates and perchlorates, and that every effort should be made to eliminate moisture from this material as well as to eliminate the presence of acid-forming constituents. Thus far, we have discussed some of the

operations in the Chemical Corps pyrotechnic program. We have also discussed some of the properties of metallic powders and oxidizing agents in dust form as well as in bulk. What, then, can we do to minimize the hazards which apparently continue to exist? First of all, it is believed that a fundamental approach in the research and development areas is required. That is to say, there should be a continuing research and development program designed to eliminate those materials which are bad actors and to replace them with materials which are less hazardous. As I have already indicated, this has been successfully achieved in certain areas: replacement of flake aluminum and auramine hydrochloride by atomized aluminum and anthraquinone yellow dye, respectively. This has also been achieved by replacing sulfur in many mixtures by sucrose which is less hazardous. Sometimes, however, this approach backfires. For example, manganese and magnesium powders oxidize readily, thus causing unstable pyrotechnic mixtures. The Chemical Corps has replaced these metals with titanium and zirconium which are stable in the presence of moisture. However, although we have achieved increased stability, we have had to sacrifice safety since titanium and zirconium are much more hazardous to handle than manganese or magnesium. Another program which the Chemical Corps has undertaken is to attempt to plasticize some of the more hazardous pyrotechnic mixtures. In the wet state, these mixtures are considerably less hazardous than similar materials in the dry state. Of course, the filling operation is one area where extreme hazard is involved even with wet mixtures. The hazards of extrusion presses are well recognized and, therefore, efforts are being directed toward the development of wet mixtures which can be poured and cast. Remote controls have been introduced into as many operations (in research and development) as possible. All grinding, granulating, mixing, pressing, etc., are accomplished by remote control. Although these systems have not yet been fully introduced in our large-scale manufacturing plants, it is believed that this can be successfully achieved when production schedules will so require. Every single new pyrotechnic mixture, as well as modifications of existing pyrotechnic mixtures, are first prepared in gram quantities and subjected to sensitivity tests to determine the hazards before a larger batch of material is prepared. If the small quantity of mix appears to be sensitive, it is safe to conclude that the large batch of mix will also be sensitive. On the other hand, if the small quantity of mix is demonstrated to have favorable sensitivity characteristics, a conclusion as to the sensitivity of the large batch cannot be drawn. This is one area where much research should be initiated - the development of sensitivity tests which truly and reliably reflect the operations and the hazards to be encountered. Various other precautions are taken with respect to minimizing the hazards in the manufacture of pyrotechnics. These are not new, and I am sure that you all employ the same techniques. For example, all sensitive materials are handled wet where possible, minimum quantities of material are handled and stored insofar as possible, limitations are placed on the number of operating personnel

in any given operating area, personnel are protected by means of aluminized asbestos clothing and face shields, good housekeeping practice is enforced, all equipment is electrically grounded, all sensitive areas have conductive floors and conductive working areas, all equipment is designed to include blow-out patches where possible, all buildings are designed to include weak walls and vents where possible, all hazardous operations are conducted behind heavy barricades, etc. The question arises, what should one do once a fire does start? The obvious answer is to effect controls to prevent the fire from starting. This is not always possible. The Chemical Corps philosophy is that copious quantities of water will control fires of reasonable magnitude. Therefore, as a result of experimental work conducted in cooperation with the Bureau of Mines, a number of years ago, all hazardous operations and working areas were equipped with sprinkler and deluge systems for the purpose of flooding the fire within minimum time after ignition. These systems are actuated by fusible alloys which melt out upon being subjected to elevated temperature. In conclusion, I again should like to express the appreciation of the Chemical Corps for our having been asked to participate in this seminar. I hope that, as a result of my presentation, we have contributed to your knowledge. At the same time, I should like to point out that I have gained considerable background as the result of having heard you recite your experiences in the propellant field. I hope that the Chemical Corps will again be asked to participate in future seminars.

<ins>Mr. J. J. Molloy, Astrodyne, Inc:</ins> Do you use deluge systems and sprinkler systems in your cells where you handle your aluminum powder?

<ins>Mr. Cutler:</ins> Yes.

<ins>Mr. Molloy:</ins> Have you had any fires resulting from that?

<ins>Mr. Cutler:</ins> No, we have not had too many fires with aluminum powder as such. However, everything we have seen and everyone we have spoken to -- including the Bureau of Mines who, in this particular case, have come down to the Army Chemical Center and run exhaustive tests -- everything, to our knowledge, indicates that one of the ways of handling, and one of the best ways of handling a metal powder fire is to deluge with water. A small amount of water will contribute to the reaction, I'll grant you, but a large amount of water will draw heat away very rapidly and put the fire out, if enough water is used. The quantity of water, of course, would be completely dependent upon the quantity of material burned.

<ins>Mr. J. O. Mack, Allegany Ballistics Laboratory:</ins> You mentioned wetting agents for titanium and zirconium powders -- normally, what do you use?

<ins>Mr. Cutler:</ins> Normally, we use water.

Mr. Mack: How about subsequent drying steps?

Mr. Cutler: With titanium powder, this is no problem. With zirconium powder, this is a terrific problem because zirconium, in the particle size that we use it, is quite pyrophoric.

Mr. Mack: I assume you are in the range of 20 micron or below?

Mr. Cutler: Oh, way below. We are in the range of 200 down to 325.

Mr. Mack: I mentioned micron.

Mr. Cutler: Oh, I'm sorry. We are in the range of - say - starting at about 30 or 40 microns on up to, maybe 100 or 150.

Mr. Mack: One other question on sensitivity testing. What normal testing do you run on metal powders?

Mr. Cutler: We normally do not run a sensitivity test on the metal powder itself. We do run sensitivity tests on the mixtures.

Mr. Mack: I was particularly interested in metal powder, in case there there was anyone with the tests.

Mr. Cutler: We run no tests on the metal powders, but, as I am sure you are aware, the Bureau of Mines does run exhaustive tests.

Captain Jenkins: Mr. Padgett, of Thiokol, I noticed that in your paper you people had conducted some tests on the sensitivity of ammonium perchlorate in the finely divided state. Do you have anything pertinent to this to add?

Mr. Harry L. Padgett, Thiokol Chemical Corporation: I will be glad to read this report on tests conducted by the Bureau of Mines. At the request of Mr. C. D. Attaway, Chief Safety Engineer, Thiokol Chemical Corporation, Longhorn Division, Marshall, Texas, laboratory tests were made to determine under what conditions dust clouds of ammonium perchlorate in air can be ignited, and whether such ignitions might produce dust explosions. A typical sample of ground pure ammonium perchlorate (Bureau of Mines Laboratory No. 2267) was supplied by Mr. Attaway. As received, many of the powder particles had formed agglomerates which could be readily broken up by light pressure with a spatula. Microscopic examination showed that the powder consisted of crystalline particles ranging in size from about 3 to 50 microns. During drying a few grams at 75°C for 24 hours, no weight (moisture) loss was measured. The tests were performed in the equipment, and according to the procedure outlined in the Bureau of Mines Report of Investigation No. 3751 - no ignitions of dust clouds of the ammonium perchlorate could be obtained in

air at normal temperature and pressure, either by the high-voltage electrical induction sparks, by electrical condenser discharge sparks, by a 40-volt AC 7-5 ampere carbon arc, or by the times flame of a 75 mg tuft of guncotton used in the test equipment. Dust clouds of the ammonium perchlorate were not ignited during rapid dispersal of small quantities through the laboratory furnace which was heated to various temperatures ranging up to 950°C.

Captain Jenkins: I imagine that if anyone is interested in that report, you could get the information on just what that report is. I think Mr. Harris has one also. They are unclassified. Thank you very much, Mr. Padgett. Mr. Greiner, I believe you have some information for us. Mr. Greiner is the Division Manager of the Safety and Explosives Department at Hercules Powder Company.

Mr. L. E. Greiner, Hercules Powder Company: I have a few remarks concerning some experience in mixing high-energy casting powders. Early in 1957, Allegany Ballistics Laboratory began to manufacture high-energy casting powders. At the beginning of the program, aluminum powder, ammonium perchlorate, and other materials had been added to single-base formulations and sensitivity data indicated no appreciable increase in sensitivity until after the powder was cut and dried. Then, double-base formulations were used, and sensitivity test results indicated no significant difference to impact sensitivity between high-energy powders and conventional double-base powders. However, high-energy powders are found to be a lot more sensitive to friction. Allegany Ballistics Laboratory continued to make this type of powder all through 1957 and 1958 and in 1958, high-energy powders of this type were also made here at the Naval Propellant Plant, at Radford, and at Kenvill also. Experience in regard to mixing such powders was very good. Only one mixer incident occurred, and this was when powder containing a small screen was returned to a mixer and a fire started. It was readily extinguished by the sprinkler system and there was no appreciable damage. That was the experience up to about three or four months ago. In the past three or four months however, there have been several fires and explosions. I thought I would mention very briefly, a resume of a few of these incidents. One fire occurred shortly after the addition of scrap powder rework to a mixer. It is believed that the scrap was too hard, and this charge burned. One fire occurred while adding solvent wetted ammonium perchlorate to a mixer, and this was a bad fire. This was the only one of any of these incidents that involved injury. Two men were burned - one fatally. This incident was believed caused by friction of the container on the mixer lid, causing ignition of the solvent vapors, or possibly, friction of the container on some spilled material on the mixer lid.

Another fire occurred when an air sparger pipe was inadvertently drawn into the mixer during a blow-down. This involved an oversolvated mix. No damage - put out by the sprinkler system. Two fires occurred toward the end of mixing cycles of oversolvated mixes - soon after mixers had been stopped for a check period. It is believed that ignition by friction of a dried skin of material in the gland area was responsible for these two incidents. The explosion occurred a minute or two after

the addition of ammonium perchlorate dry to a mixer. Other than the two incidents mentioned there was relatively no damage at all. I don't mean to minimize the incidents but generally they were controlled by the sprinkler system, with little more than possibly some scorching of paint. Now these incidents have caused a great deal of attention to be focused on the mixing operation and equipment. Discussions have been held by representatives of all four installations mentioned in regard to mixing of high energy double-based formulations and the hazards involved. These have been open sessions where everyone's ideas were welcome; there was no agenda; it was the same type of idea that we here today are participating in, free exchange of ideas. Here are some of the changes in procedure as well as mixer design that have been suggested in these meetings to date. All of these mixers involved were sigma-blade mixers equipped with conventional packing glands. However, with the exception of one mixer at ABL, there was no packing in the glands of any involved. Yet it appears that some of the incidents were caused by friction of dried material in the vicinity of the glands. Some of the suggestions made to eliminate friction were: Reduce the thickness of metal of the brass mixer gland collar or insert at the point of minimum clearance between the shaft and the insert. Another suggestion was to introduce solvent into the gland area from the outside of the gland during mixing. Another was to moisten the gland area with a small amount of solvent inside the mixer, whenever mixing was interrupted. Another was to increase the clearance at the point where the shoulder or hub of the shaft is adjacent to the mixer wall. Another: Install teflon inserts in mixer glands; install slinger rings on the shaft beyond the glands to prevent migration of material along the shaft into bearings. Another: Design future mixers of polished stainless steel. Still another: Utilize a type of mixer without submerged glands. Now there are others but those are the things that we have talked about so far. Changes in procedures have been suggested also. It has been suggested and tried, formulations be over-solvated during mixing procedure with excess solvent removed by sparging of air or inert gas at end of mixing cycle and this has been done. However, with this procedure there still is a problem of preventing dry skins of material from forming within the mixer. The mixers are stopped to obtain samples or make inspections. To the best of our knowledge none of the 4 installations are currently over-solvating during mixing but I learned just recently, in the past hour, that NPP has conducted some very interesting experiments regarding mixers solvated and over-solvated and I'll ask them when we finish if they will please give a resume of the recent experimental work done. Now insofar as sensitivity to detonation is concerned, tests indicate that ammonium perchlorate wet with a small percentage of solvent is more sensitive than dry ammonium perchlorate. If dry ammonium perchlorate is added to a mixer, there must be at some stage in the cycle regions where perchlorate is wetted with a small amount of solvent, thus creating a sensitivity situation which is akin to dynamite. For this reason Hercules, as of now, prefers wetting the ammonium perchlorate with solvent before the addition to a mixer. We may be forced to abandon this position however,

on account of an overriding preference to make all additions by remote control. We have not yet successfully solved the problem of transferring wetted, or damp, ammonium perchlorate from a container into a mixer. So, at the present time, while work is underway to design or utilize altered equipment for the loading of mixers from the outside, from outside mixer bays, we have instigated the procedure of providing operators with aluminized asbestos or other suitable fabrics, plus hoods and gloves. That is about the status of the mixing problem as we see it now. Are there any questions?

Captain Jenkins: Quite a few people expressed interest in the mixer problem. Mr. Lewis, of Allegany Ballistics Laboratory, did you have anything that you would like to add, or any questions you would like to ask about it? All right, Mr. Haite?

Mr. Haite: You mentioned some impact sensitivities and that your tests showed that the ingredients were more-or-less nonsensitive, or that you didn't change the sensitivity. What impact sensitivity tests did you run?

Mr. Greiner: I didn't say they were "nonsensitive". I said they were no more sensitive than ----

Mr. Haite: Well, that is what I meant - no increase in sensitivity?

Mr. Greiner: I don't know that I can give that. Dr. Ball, do you recall? It is a modified machine, isn't it?

Mr. Haite: Well, in the composites - at least it has been our experience that the sensitivity as measured by the falling ball does not agree with the sensitivity, - other sensitivity tests; that is, for material that you think is considered more hazardous, for example, an 80% loaded oxidizer material you would consider to be more hazardous and more sensitive than a 60% oxidizer material of the same formulation - the same basic degrees. However, on the falling ball impact tester, it is entirely possible that the 60% will show up as more sensitive than the 80%. I, myself, don't put an awful lot of strength in the impact sensitivity tests. This may be the reason why you thought you were getting a mixture that was no more sensitive, and actually, you were getting a more sensitive mixture.

Dr. A. M. Ball, Hercules Powder Company: I agree with you entirely that the Bureau of Mines impact tests tell you very little about what might happen in the way of a detonation. However, it is the general feeling throughout the industry that it does tell you something about the sensitivity toward ignition, and during mixing operations, we are just about as scared of starting fires as we are of starting a detonation.

Dr. A. B. Amster, Naval Ordnance Laboratory: I will have a few more remarks later this afternoon on impact testing; however, I am pleased to see that it is falling into a little bit of disrepute as far as hazard is concerned. There is one thing, though, that I think is worthwhile remembering - in particular, at Allegany Ballistics Laboratory up in the humidity-laden climate of western Maryland, and perhaps too, the Naval Propellant Plant down here and that is, you have to bear in mind (and normally it is forgotten) that the results depend to a great extent on humidity. We have done some work on the impact tests at NOL. One can make some reasonable assumptions that the sensitivity is largely affected, or is largely caused, by the adiabatic compression of the included gas or gas bubbles, and this, in turn, might be affected by the amount of water. Unless you make some effort to control humidity and perhaps temperature of the included gas too, the statistical dispersion of your results is going to be so wide that it will lay open to question the validity of the impact data, regardless of the significance that you want to attach to your final results.

Mr. Mack: I'd like to mention that our test room is completely air-conditioned, controlling the constant humidity and temperature.

Mr. Haite: I had several items. You mentioned that the explosion occurred shortly after the dry ammonium perchlorate was added to the mixer. Was this after you turned the mixer on?

Mr. Greiner: I think it was estimated that it ran, something like 30 to 50 revolutions.

Mr. Haite: I didn't catch the cause, then.

Mr. Greiner: Well, I don't know that we know the cause exactly.

Mr. Haite: Was there a "possible"?

Mr. Greiner: I will farm out this answer. What has been your experience, Mr. Buckles?

Lt Commander H. Buckles, Naval Propellant Plant: The only thing that I think we could mention in regard to it is that we have been educated more here in the past few weeks than we had been at that time. We have found, both ABL and ourselves, that AP when it is wet within specific percentages of acetone becomes very sensitive to impact, and I think in this particular instance, we were processing a formulation which had a minimum amount of nitrocellulose and we had very recently added dry AP to the mixer and ran for about a minute-and-a-half when, very suddenly, as some of you saw yesterday, it "let go" and sort of fractured a few walls. We believe now that what happened was that some of the AP had gotten into the gland and worked between the shaft and the gland and the blade flexing the shaft impacted against the gland and caused this initiation within the gland

area itself which, of course, then spread to the matrix and gave us an epicenter somewhere over our forward blade and the mixer and, of course, completely demolished the thing. This, we feel, is what happened. In other sigma blade mixers we did not have a dissimilar metal gland, but had a stainless steel wall where the gland was integral with the wall and we also had stainless steel shafts. We feel that our flexing in these shafts is due to the blade being distorted by the weight of the matrix and the torque of the motor. We had an all-around clearance of approximately 30/1000 in our shafts, and extreme galling appeared on the shafts themselves so we are quite sure that the blade was being distorted to the degree where it would contact the glands and, naturally, a propellant during the mixing is being extruded through these openings. We feel that blade-flexing is shocking the propellant that is between the glands and the shaft, and is causing these ignitions. In order to correct this, we have followed ABL's line of thought on this and have now eliminated any gland metal in there at all. We have nothing but teflon inserts. We certainly hope that this is going to be the answer to the problem, and we are indebted to ABL for their thinking in this matter.

Mr. Haite: The teflon insert - do you ever find that teflon is rough on metal?

Mr. Greiner: Let's ask Jim Mack about it.

Mr. Mack: We have had up to four and five months' wear and have found no appreciable wear on the shafts themselves. Most of it was taken up in the teflon inserts. This depends a lot on the particular design of the insert itself where you take the wear on the insert.

Captain Jenkins: Mr. Stuckey, do you have anything that you might want to add to this on packing glands?

Mr. Max T. Stuckey, Thiokol Chemical Corporation: I don't know that I want to add to it. We had a little incident in our plant which, we figure, was started in a gland so we removed the packing in our gland. We have had a lot of difficulty with them. We have tried all types of clearances, and we had exudation of material - it dropped down into the tilting mechanism and everything else. We finally went back to packing. We believe in it very strongly again, although I was on the other side of the fence. We use a rather soft packing. We started out with cotton. I think most of us use jute, now. We soak it in a polymer, a thin polymer. Most of us require at least 48 hours although the longer we leave it in the polymer, the better off we think we are. We get a slight exudation of polymer into the mixer. We find that most of the divisions are standard in this now. We change our packing weekly. We find very little contamination of the packing, usually just the inside of the very first ring of packing. If you are using the same material all the time, you could probably wash that and remove most of it. I think all of us now are using jute packing soaked in polymer. It can be used either for vacuum or not. We don't use vacuum at Elkton at the present time.

Mr. C. M. Havlik, Naval Ordnance Test Station: We are pretty well committed also to packing. I don't think we have ever gone to the system where we do not use packing. We are using a teflon asbestos commercial material, and we replace fairly regularly. I had a question for the speaker. I understand that ABL is now designing a new friction sensitivity tester. Is there anything new on this? It was in the trying stage when I heard of it.

Mr. Mack: The answer is yes, Chuck. We are now in the process of trying to zero the whole thing in, and as you are well aware, this is a long-term proposition. It looks very promising at this time, and we hope to have some reports and documents to substantiate these views.

Captain Jenkins: Mr. Greiner, you said you were very interested in the experimental work being done here at the Naval Propellant Plant. Are there any of the NPP people here who could furnish us with some edification on that - on the work you are doing?

Mr. T. J. Sullivan, Naval Propellant Plant: In order to clear up the answer as to whether or not the flow-down procedure in the oversolvated mixes had anything to do with the fire that occurred, we made a small mix in a 1-gallon mixer. The mixer, unfortunately, had packing but the clearances on the blades were such that they were less between the blade and the shell than in the glands of the production-type mixer, so we felt that the test would probably be OK to run and to check. We made a 20/88 mix using a solvent composition of about 25% total solvent. The alcohol-to-acetone ratio was 40 alcohol, 60 acetone. That is what makes it oversolvated. A so-called "undersolvated" mix would be the same total solvent, but would have about 65% alcohol and 35% acetone and would get a blowdown into the two-hour mix cycles - it would just be full. We ran this mixer through the regular mix cycle two hours or so, and then started the blowdown procedure. After getting it to the point where we would have taken it out and extruded it, we just left the lid open and let the air blow on it and ran the mixer for another 5½ hours. At the end of that 5½ hours, the material in the mixer was like gravel - very hard - sandy - and when analyzed for moisture, it was less than ½% moisture. So, we feel that as long as we didn't get any metal-to-metal contact to produce its spark or create a friction condition, that the dry propellant alone running around in the mixer - I felt, anyway - was not enough to set the mixer off. Going back again to the shafts, we made a second setup which was just a bearing with a sleeve much like the bearing area on the large mixers. We designed it so that the rotational velocity was the same as the rotational velocity in the bearings in the large mixers. We fitted a hydraulic piston to the sleeve so that the propellant would be forced through and around the clearance between the shaft and the bearing openings. This was going for something like 16 hours with an undersolvated mix and nothing happened. We took that out, and it was pretty near dry. Then we ran it also for 16 hours with an oversolvated mix, with the same results - no incidents. This, again, led us to believe that

unless you have some condition where you get metal to metal contact and get some scratching or scraping somewhere, that the thing is pretty safe, whether it is under-solvated or over-solvated. In the matter of sensitivities, although, maybe none of them are real good, I think that from one mix to another, we should be at least relative. When we start getting around 100 or 125 mm before we get five failures to explode or to detonate, that is pretty sensitive stuff and we found that whenever you get nitrocellulose, nitroglycerine and AP together, no matter what the proportions, that you have this sensitive condition existing in the mix.

Captain Jenkins: Anything else from the floor?

Dr. C. Boyars, BuOrd: One thing about these high energy systems and the addition of ammonium perchlorate, it is bad enough when we have ammonium perchlorate, which is a monopropellant, mixed in with nitrocellulose or nitroglycerine, which are also monopropellants. You triple your danger right there, any one can set off the others. When we start adding other materials to this minor ingredient, you may be introducing another hazard. I'm thinking specifically of copper. Sometimes we formulate, for various reasons, using copper salts. Sometimes we process in copper or brass. Now this is apparently bad; copper and perchlorate seem to be incompatible. At least the manufacturers of ammonium perchlorate have found, the hard way, that they have to eliminate brass and copper from their operations. If you want to get into molecular structure, you could even explain why this should be so, but this has apparently been the experience quite consistently in the U.S., and I think it is something we ought to consider when we process these propellants containing ammonium perchlorate; not to use copper or brass screens, copper or brass fittings. The only thing I know against this is for some years the British claim to have processed ammonium perchlorate propellants in copper or brass without any explosive incident. I would like to know what the experience of others has been in this regard.

Mr. Sullivan: I may be wrong on this, but I think that what we found was that the ammonium perchlorate and copper are ok together but if you should get water in the system the ammonium perchlorate forms a perchloric acid and reacts with the copper and forms something like an azide or some chemical compound that, when it dries, can be very sensitive. So long as everything is dry and the perchlorate and copper come together, there doesn't seem to be any indication that this would be hazardous. Also, inadvertently in this bearing test that we made up, the bearings were made of bronze and that was run for 16 hours.

Captain Jenkins: Well, Mr. Greiner, you mentioned earlier that a lot of your troubles had been or had come about from using scrap.

Mr. Greiner: There was just one incident, as I recall.

Captain Jenkins: Oh, just one. Mr. Marsh had mentioned this morning that the best thing to do with scrap is "throw it away" - or is this in a different field?

Mr. Greiner: "Scrap" was the wrong word, it probably should have been "rework" - which is essentially the same - it was a previous mix that had not come up to expectations.

Mr. Sullivan: Processing these over-solvated mixes of the hybrids, we get heels in the presses naturally and these are saved and, as a standing rule, we put back about 50 pounds per mix and the heels seem to get ahead of the mix. At one time we made a mix using nothing but what you might call "rework" or "scrap" - 300 pounds of heels. We put some acetone or alcohol in this and worked it up and, of course, it worked, but I don't know how many times we want to do with 100% scrap. It is normal to put in at least 50 pounds of scrap in every mix.

Mr. W. E. Schaefer, DuPont: Mr. Greiner made reference to perchlorate double base formulations being more sensitive to friction than to impact. What sort of friction test was used?

Mr. Greiner: I don't recall, at the moment, do you remember, Jim?

Mr. Mack: That was a so-called "impacting friction". We dropped several of them around a pivot point and allowed the wheel to rotate around the point and this is one of the areas where we are quite certain that we are not getting a true friction test, but it is the one that has been used for a long time in the field to give a friction identity, at least, to some materials.

Mr. Schaefer: It is better than nothing.

Mr. Mack: It is better than nothing, yes. That is the point previously brought up, that we are attempting to design a friction machine which we hope at least will give a spread on ingredients to show a sensitivity. As yet, we are not ready to publish any complete data, but we hope to be some time this summer.

Mr. Schaefer: How did this pendulum shoe test compare with the sliding rod sensitivity test?

Mr. Mack: I'd like to pin that one to someone who is using the sliding rod test. We do not use it. We do not have any correlated data on our own installation.

Captain Jenkins: Does anyone use the sliding rod test?

Mr. Mack: I think NPP does, yes, but how much faith anyone has in it-------.

Captain Jenkins: Mr. Schaefer, you had expressed a particular interest in small mixes and so far we have been dealing with the big ones, so if you don't get answers to your satisfaction, you bring that up later, will you?

Mr. L. J. Shaw, Air Force Plant 66: This business of scrap depends entirely on what you are mixing and what sort of propellant you are talking about. Our experience is the opposite of what you have stated here. We have reduced our scrap to almost nothing by throwing reworked grains into Baker-Perkins mixer and using it for grinder and in effect, have never had an incident involving such a procedure. We take an 87- or 90-pound grain and put it back in a 400-pound mix and grind the whole thing up and use it dry without a slurry or anything and we have never had an incident. We broke up a lot of mixers, but we have strengthened the bearing surface on the mixer and we, in effect, now use it for a crusher. In addition to the mixing, we crush it at the same time. We do the same thing with perchlorate rework, however, we don't crush the grain. We do use the shavings where we have trimmed them to size, and we have reduced our scrap and rejects to practically nothing except for what falls on the floor.

Mr. Haite: I think this might be a point to mention about mixers -- we have been looking for years at vertical mixers to eliminate the submerged packing plan. They have all been tried with varying amounts of success, not every mixer on the market, but most of them. We finally have this vertical mixer now that we think might be the answer to the problem on process. It is more or less a combination of the input from various propellant people in the country and it looks like it is going to do a real good job. There are none in operation yet; they are being readied to put into operation. This may be one of the answers to your mixer problem.

Mr. D. E. Endsley, AFMSS, Air Force: Mr. Greiner does have one problem, I believe, that hasn't been solved and I don't think we have had a response from the floor and that is the transfer problem of ammonium perchlorate wet. Can anyone help him out on this?

Mr. Haite: How do you mix your ammonium perchlorate solvent? How do you get it wet in the first place?

Mr. Mack: I hate to admit this in public, but usually it is "bucket to paddle". You see at ABL we are concerned with vary small amounts in propellant manufacture in terms of mixing. We are basically working in the areas of one pound or quarter pound mixer.

Up to a 10-pound mixer, and up to 120, we go to NPP or Radford or some other installation for manufacture of large quantities of casting powder, for our use. Here, of course, is where the scrap comes in, and I imagine that they are probably using a container and adding the solvent to the container, and stirring it up with a paddle.

Mr. Greiner: That is right.

Mr. Mack: So it's a bucket-and-a-paddle, again.

Mr. Haite: Can't you just dump the bucket into the mixer? Just turn it upside down and dump it in? But, you want to do it remotely.

Mr. Mack: This concerns doing it remotely, yes, but what it requires is scraping the bucket down with a rubber spatula or something of this nature. We are talking in terms of an area of about 15% to 20% wet. AP will not quite flow, but almost.

Mr. Haite: We have a similar situation which has developed in the past which we have tried. This is to -- instead of having just a simple bucket, in the bottom of your bucket you can have a diaphragm of some type that you can force out.

Mr. Mack: Actually pop the diaphragm out --

Mr. Haite: One way or the other, yes, with your can in position. You can either have a plunger in the bottom of the can which pushes the material out, or break the diaphragm.

Mr. Mack: This is in a plastic container, or a metal container?

Mr. Haite: Either one. It was done in metal with wooden fixtures, but you can take your choice. It is not a finished item - a manufactured item - but we did do the same thing.

Mr. Mack: We will probably try it.

Mr. E. M. Rochford, Hercules Powder Company: In order to verify Mr. Mack's statement, we made a few thousand pounds of this high-energy base grain and followed this procedure. We put the ammonium perchlorate in a bucket and poured some solvent in on top of it. This comes out like a pancake batter. We dumped it in the mixer, and saved a little solvent to rinse the container. It is not a production method and we do not intend to operate that way on real production.

Captain Jenkins: Anything else to bring up? The next presentation will be given by Mr. Owings, of the Naval Propellant Plant.

Mr. John T. Owings, Propellant Program Officer, Office of the Technical Director:

STATIC IGNITION SENSITIVITY OF ETHER-ALCOHOL-ACETONE AND PROPELLANT DUST

In the manufacture of single-base propellant, the basic ingredient nitrocellulose (NC) is dehydrated with alcohol, the alcohol-wet NC is mixed with ether and various additives (stabilizer, plasticizer, deterrent, etc.), and the resultant mass is kneaded or macerated into a heavy "dough" and extruded as perforated rods which are subsequently cut into solvent-wet propellant grains of the desired length. In finished-stage operations the solvent-wet propellant grains are subjected to a solvent recovery, water extraction and air drying sequence of operations to reduce the residual solvent content to the desired level, and then the finished propellant is blended and packed. In existing type operations, the solvent-wet propellant is repeatedly exposed to atmospheric oxygen during movement from one "batch" operation to the next which creates combustible vapor/air mixtures which are sensitive to spark ignition from static electricity. In addition, the finished propellant is repeatedly handled during the finishing operations which creates dust laden atmospheres as well as dust films in buildings and on equipment which are sensitive to spark ignition from static electricity. Similar static hazards exist in the manufacture of double-base, triple-base and composite propellants.

The purpose of this paper is to review the static hazards study conducted at Indiana Ordnance Works relative to the manufacture of single base propellant. The static hazards study was (1) an intensive investigation of the electrical properties and behavior of solvent-wet and finished propellant grains under both static and dynamic conditions, (2) an experimental evaluation program to establish the static ignition sensitivity of diethyl ether, ethyl alcohol and acetone vapors as well as propellant dust films and dust laden atmospheres, and (3) a quantitative study of the nature, origin and magnitude of static charges developed by men and machinery.

THEORY OF STATIC ELECTRICITY

Static electricity may be defined as an electric charge at rest. For every static charge of polarized electricity (either a positive or negative charge) on the surface of a substance, an equal charge of opposite polarity must be present on a nearby object. Static charges may be created in two ways: (1) by contact and separation, and (2) by electrostatic induction.

When dissimilar materials are pressed together, free electrons may shift from the surface of one material to the surface of the other. On separation, the new distribution of electrical charges will persist if one or both of the materials are nonconductors. The transfer of electrons by contact and separation is often facilitated by frictional contact, such as rubbing. The rubbing action does not create the charge but is a means of bringing more points on the surface in contact. The extent and direction of electrical shift depend on the nature of the materials and are usually in accordance with their position in the triboelectric series as presented in Table A. Each substance in this table becomes positively charged when rubbed against any substance lower in the series.

Electrostatic induction may be defined as the act or process of separating positive and negative charges on the surface of any neutral substance when placed near an electrified object. A charged object will induce a charge of opposite polarity on the nearest face of a neutral substance and a charge of like polarity will appear on the opposite face of the neutral substance. The neutral substance may be either a conductor or a nonconductor; however, the surface resistivity to the movement of an electric charge is much greater in the case of a nonconductor than a conductor.

TABLE A
TRIBOELECTRIC SERIES

(+) Asbestos
Glass
Mica
Wool
Cat Fur
Lead
Silk
Aluminum
Paper
Cotton
Wood
Sealing Wax
Ebonite
Ni, Cu, Ag, Brass
Sulfur
Pt, Hg
(-) India Rubber

The following typical examples are illustrations of the phenomenon of electrostatics:

1. An individual may accumulate a static charge by contact and separation with rugs, floors, walkways, etc., when wearing nonconductive shoes, especially when the atmospheric humidity is relatively low.

2. A moving vehicle may accumulate a static charge by contact and separation since the tires are essentially nonconductors.

3. A tank truck may accumulate a static charge by contact and separation due to the liquid flowing through a discharge pipe.

4. A building or elevated object may accumulate a static charge by electrostatic induction from an electrified cloud.

5. Propellant grains may accumulate a static charge by contact and separation from movement through a pipe or movement during the air drying, blending and packing operations.

6. Belt-driven machinery may accumulate a static charge by contact and separation of a belt passing over drive pulleys.

Regardless of whether static charges are created on substances by (1) contact and separation, or (2) electrostatic induction, the unlike charges continually seek to recombine and neutralize the electrical potential. As charged bodies are moved nearer to each other, a spark will arc between the two bodies before contact if the initial potential is greater than the minimum sparking potential of 275 volts. On the other hand, an electrostatic charge may be readily dissipated by (1) proper grounding, (2) proper materials for equipment and wearing apparel, and (3) ionization of the atmosphere.

The accumulation of static charges on adjacent objects, separated by a dielectric, creates a strong electrostatic field capable of storing

electrical energy, which functions as a condenser. For example, a condenser may be formed between an individual's feet and the ground with the shoe soles acting as the dielectric. The capacitance of an average size man, approximately 170 pounds in weight, wearing normal nonconductive shoes, 0.73 cm thick with a dielectric constant, (K)=5, and an area of 250 sq cm, may be estimated from the following equation:

$$C = \frac{0.088K\ A}{d}$$

$$C = \frac{0.088 \times 5 \times 500}{0.73} = 300\ \text{mmfd}$$

where: C = Capacitance (mmfd)
A = Area of both shoe soles (sq cm)
K = Dielectric constant of shoe soles
d = Separation from ground (cm)

The literature reports and experimental findings confirm that the static potential accumulated on a man's body is primarily dependent on the type of clothing worn by the individual and the relative humidity of the atmosphere. For example, the maximum potential which a man can accumulate on his body is about 10,000 volts when wearing nonconductive shoes and either cotton or wool clothing. The energy equivalent to the static charge accumulated on a man's body may be estimated from the following equation:

$$W = \frac{CE^2}{2}$$

$$W = \frac{300 \times 10^{-12} \times (10{,}000)^2}{2} = 0.015\ \text{joules}$$

where: C = capacitance (farads)
E = potential (volts)
W = energy (joules)

For comparative purposes, the voltage required for minimum ignition energies may be placed on a man-equivalent basis by use of the expression:

$$V_1 = V_2 \sqrt{\frac{C_2}{0.0003}}$$

where: V_1 = man-equivalent voltage
V_2 = voltage at minimum ignition
C_2 = capacitance at minimum ignition

EXPERIMENTAL

The first part of the experimental program was an investigation of the electrical properties and behavior of solvent-wet and finished propellant grains under both static and dynamic conditions. The magnitude of static accumulation on propellant grains and machinery, created by pneumatic conveying (airveying) of finished propellant grains, increased as the electrical resistance of the conveying system was increased and as the relative humidity of the surrounding air decreased. By grounding the pneumatic conveying tube and powder receiving container, which comprised the conveying system, the static charge was effectively discharged as fast as generated due to the lower resistance path to ground. On the

other hand, the static accumulation was increased by inserting rubber and/or lucite insulators between the powder receiving container and ground to increase the electrical resistance to ground.

The static charge generated by repeated contact and separation of powder grains when airveyed was a straight line function of the relative humidity of the atmosphere. As the relative humidity increased, moisture collected on the nonconductive surface which made the propellant grain a better conductor of electricity. The moisture film which formed on the grain decreased the surface resistivity and provided a conductive path for opposite charges to recombine or flow to ground. The effect of humidity on static accumulation relative to airveying finished 105 mm Howitzer propellant grains is illustrated by the data presented in Table B.

TABLE B
STATIC POTENTIAL ACCUMULATED BY AIRVEYING FINISHED PROPELLANT GRAINS

Relative Humidity (%)	Moisture of Powder (%)	Capacitance of System (mmfd)	Measured Potential (volts)	Energy (joules)	Man-Equivalent Voltage
20	0.45	65	20,690	0.01391	9637
30	0.45	65	15,920	0.00824	7416
39	0.43	65	13,740	0.00614	6400
50	0.43	65	9,760	0.00309	4546
64	0.60	68	4,765	0.00077	2272
71	0.40	65	1,495	0.00007	696

The results of airveying solvent-wet powder indicate no appreciable static accumulation. Test samples of solvent-wet powder were airveyed, and in every case, no static accumulation was detected during the first five passes through the conveying tube. During that time, it was postulated that contact and separation were essentially contact of vapor on the grain with vapor on the surface of the conveying tube. As the test runs were repeated, the vapor concentration decreased and the measured charge increased to an average of 980 volts during the next ten passes. Repeated passes, after leaving the test sample exposed to the air at ambient temperature for 24 hours, decreased the vapor concentration to the point where contact and separation of the grain with the conveying tube created a static charge of 4500 volts.

The second part of the experimental program was to establish the static ignition sensitivity of diethyl ether, ethyl alcohol, and acetone vapors as well as propellant dust films and dust laden atmospheres. The minimum ignition energy was determined for both propellant dust laden atmospheres and various thicknesses of dust films.

The static ignition sensitivity of propellant dust films and dust laden atmospheres varies with the relative humidity of the air, particle

size, film thickness, concentration, moisture, and composition of the dust. Tests indicated that the energy required to ignite propellant dust increased directly with the moisture, particle size of the dust, and the relative humidity of the surrounding air. Dust collected from plant operations with inert materials present required a greater ignition energy than synthetic dust free of inert materials. In addition, these tests indicated a critical dust film thickness of 0.006 - 0.0125 inch for minimum ignition energy. These experimental data are presented in Table C and Figures 1 and 2.

TABLE C
STATIC IGNITION SENSITIVITY OF PROPELLANT DUST

Propellant Dust Composition	Particle Size (microns)	Dust Films: Energy (joules)	Dust Films: Man-Equivalent Voltage	Dust Cloud: Energy (joules)	Dust Cloud: Man-Equivalent Voltage
M1 Plant	149	0.2250	38,730	0.1620	32,860
	74	0.0841	23,750	0.1320	29,760
	47	0.0529	18,840	0.0563	19,370
	37	0.0265	13,280	0.0176	10,840
M1 Synthetic	149	0.0680	20,770	0.1634	33,000
	74	0.0221	12,120	0.0545	19,050
	53	0.0175	10,840	0.0221	12,120
	43	0.0128	9,230	0.0137	9,550
M6 Synthetic	149	0.0722	21,930	0.0900	24,530
	74	0.0221	12,120	0.0545	19,050
	53	0.0194	11,360	0.0063	6,450
	43	0.0096	8,000	0.0046	5,550

Ignitibility limits and the minimum ignition energies were established for combustible vapor/air mixtures of ether, alcohol and acetone. In every case, the lower ignitibility limit was more sharply defined and more easily determined than the upper limit. The flames observed for ether ignitions were faint bluish-white in color which were difficult to see near the upper limit even in a dark room. An ether mixture near the upper limit of 10.0% by volume would often fire the second time. The ignition flame for ether near the upper ignitibility limit was difficult to detect and above this level could not be discerned. The upper ignitibility limit of ethyl alcohol was not determined since the vapor pressure of ethyl alcohol is only 100 mm Hg at 35°C which limits the accurate vaporization and mixing above 14% by volume. Experimental data illustrating the sensitivity of ether, alcohol and acetone at various concentrations to spark ignition from static electricity are presented in Table D and Figure 3.

UNCLASSIFIED

FIGURE 1

EFFECT OF DUST FILM THICKNESS ON STATIC IGNITION SENSITIVITY OF SMOKELESS PROPELLANT DUST

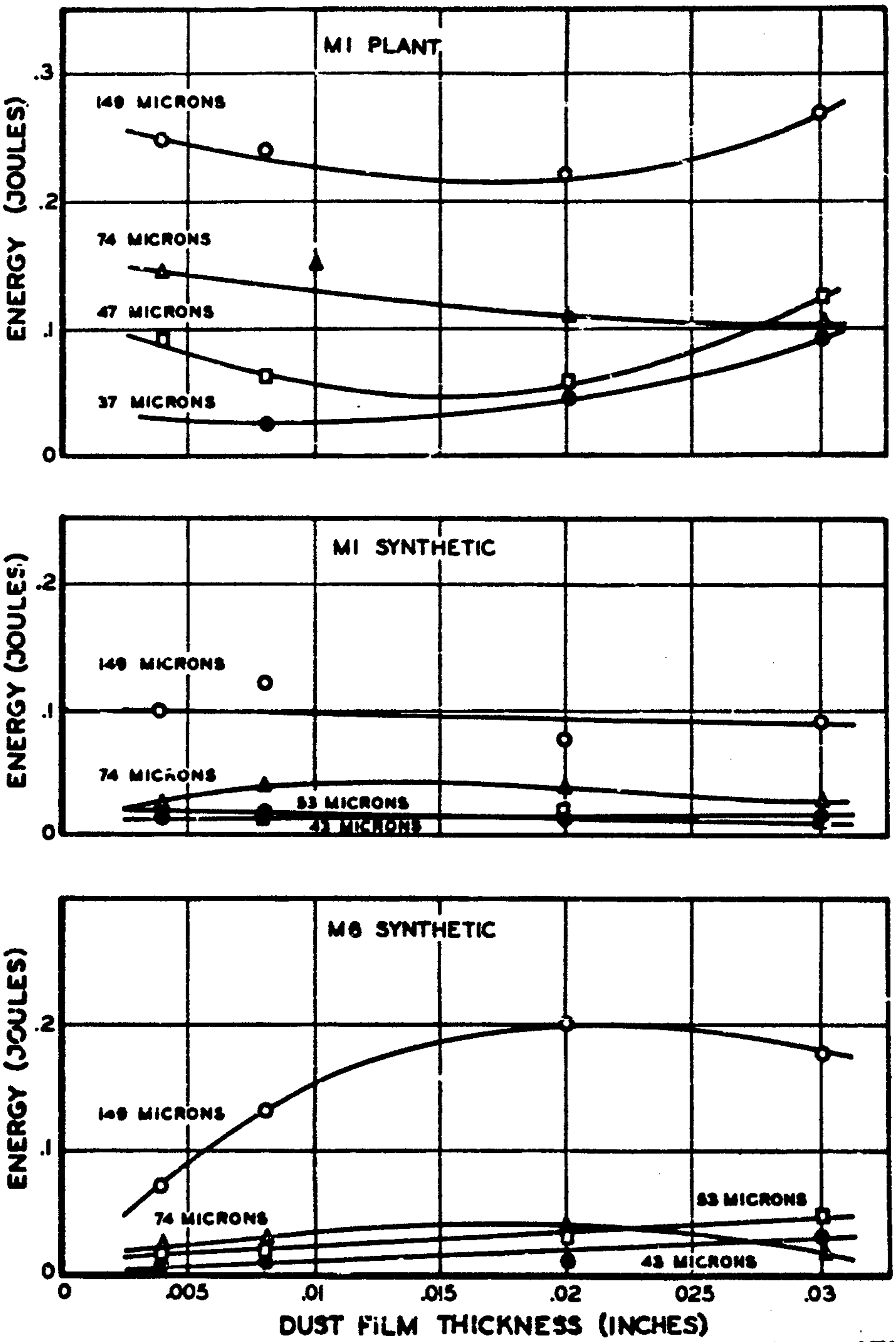

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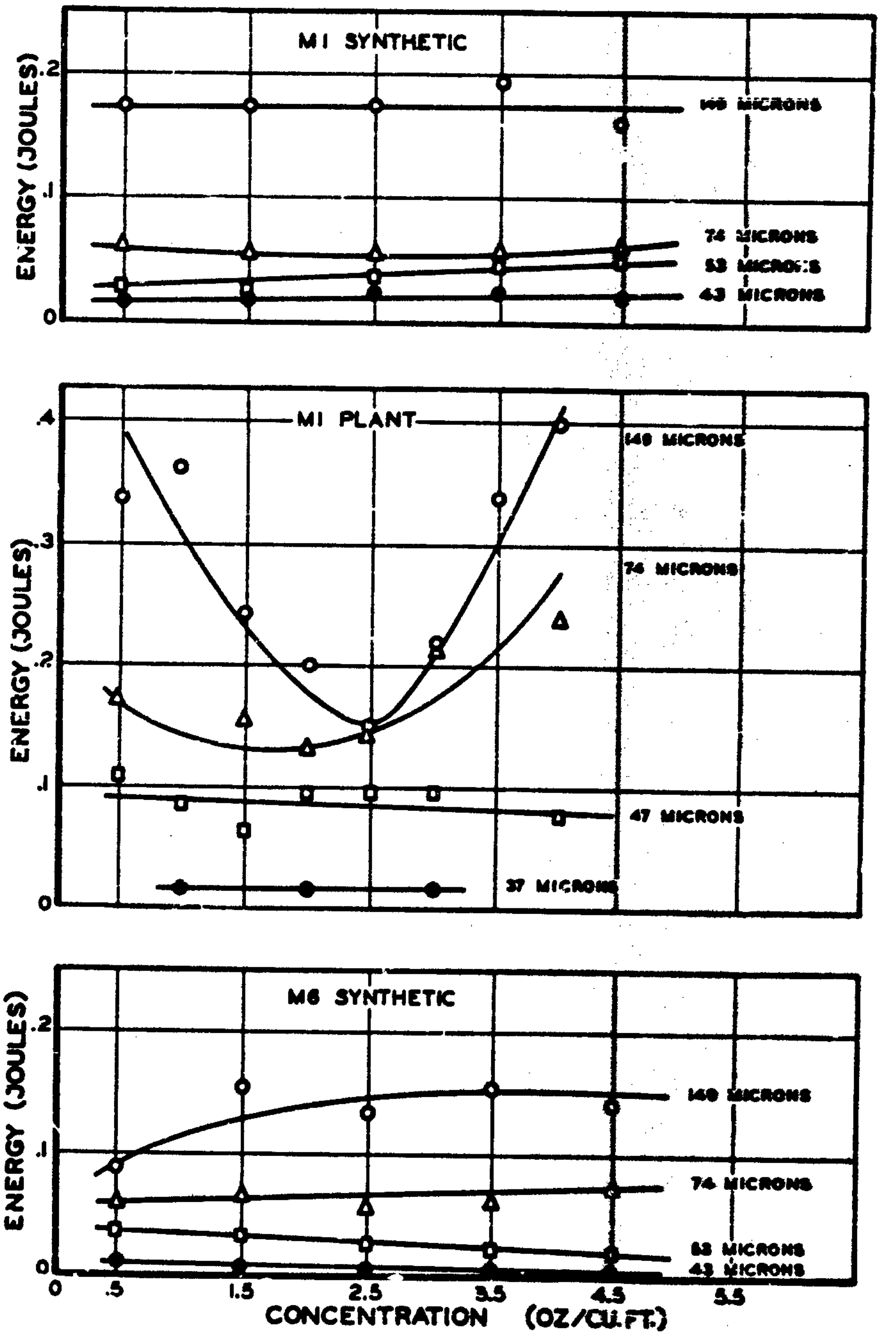
FIGURE 2 UNCLASSIFIED

EFFECT OF DUST CONCENTRATION ON STATIC IGNITION SENSITIVITY OF SMOKELESS PROPELLANT



 UNCLASSIFIED

TABLE D

STATIC IGNITION SENSITIVITY OF ETHER-ALCOHOL-ACETONE

Concentration (% by vol)	Diethyl Ether Energy (joules)	Diethyl Ether Man-Equivalent Voltage	Ethyl Alcohol Energy (joules)	Ethyl Alcohol Man-Equivalent Voltage	Acetone Energy (joules)	Acetone Man-Equivalent Voltage
1.7	Did not ignite	--	Did not ignite	--	Did not ignite	--
2.0	0.11750	28,000	"	--	"	--
2.5	0.00310	4,610	"	--	"	--
3.0	0.00044	1,700	"	--	"	--
3.5	0.00014	980	"	--	0.09685	28,390
4.0	0.00013	930	"	--	0.01581	10,250
4.5	0.00013	930	0.11838	28,080	0.00257	4,130
5.0	0.00015	1,010	0.02470	12,840	0.00131	2,950
5.5	0.00017	1,060	0.00606	6,360	0.00081	2,330
6.0	0.00025	1,290	0.00143	3,060	0.00066	2,150
7.0	0.00385	5,060	0.00056	1,940	0.00075	2,240
8.0	0.02304	12,360	0.00044	1,700	0.00084	2,350
8.5	0.09310	24,900	0.00042	1,660	0.00091	2,450
9.0	0.24713	40,600	0.00042	1,660	0.00106	2,650
10.0	0.36340	48,350	0.00046	1,760	0.00206	3,750
10.9	Did not ignite	--	0.00063	2,040	0.01606	10,450
12.7	"	--	0.00131	2,960	0.13831	30,350
14.0	"	--	0.00209	3,690	Did not ignite	--
17.8	"	--	0.02900	13,900	"	--
Ignitibility Limits	2 to 10% by volume		4.5 to 17.8+% by volume		3.5 to 12% by volume	
Explosive Limits	1.7 to 48% by volume		3.28 to 19% by volume		2.5 to 13% by volume	

The third part of the experimental program was a quantitative study of the nature, origin, and magnitude of static charges developed by men and machinery. The accumulation of static electricity on an individual's body is a function of the relative humidity of the air, the type of clothing worn by the individual, the electrical characteristics of the flooring, and the dielectric properties of the shoe sole material. The data presented in Table E were obtained by measuring the static voltage created on an individual's body, under varying conditions, when rising from a leatherette-covered office chair.

FIGURE 3

UNCLASSIFIED

EFFECT OF ETHER-ALCOHOL-ACETONE CONCENTRATION ON STATIC IGNITION SENSITIVITY

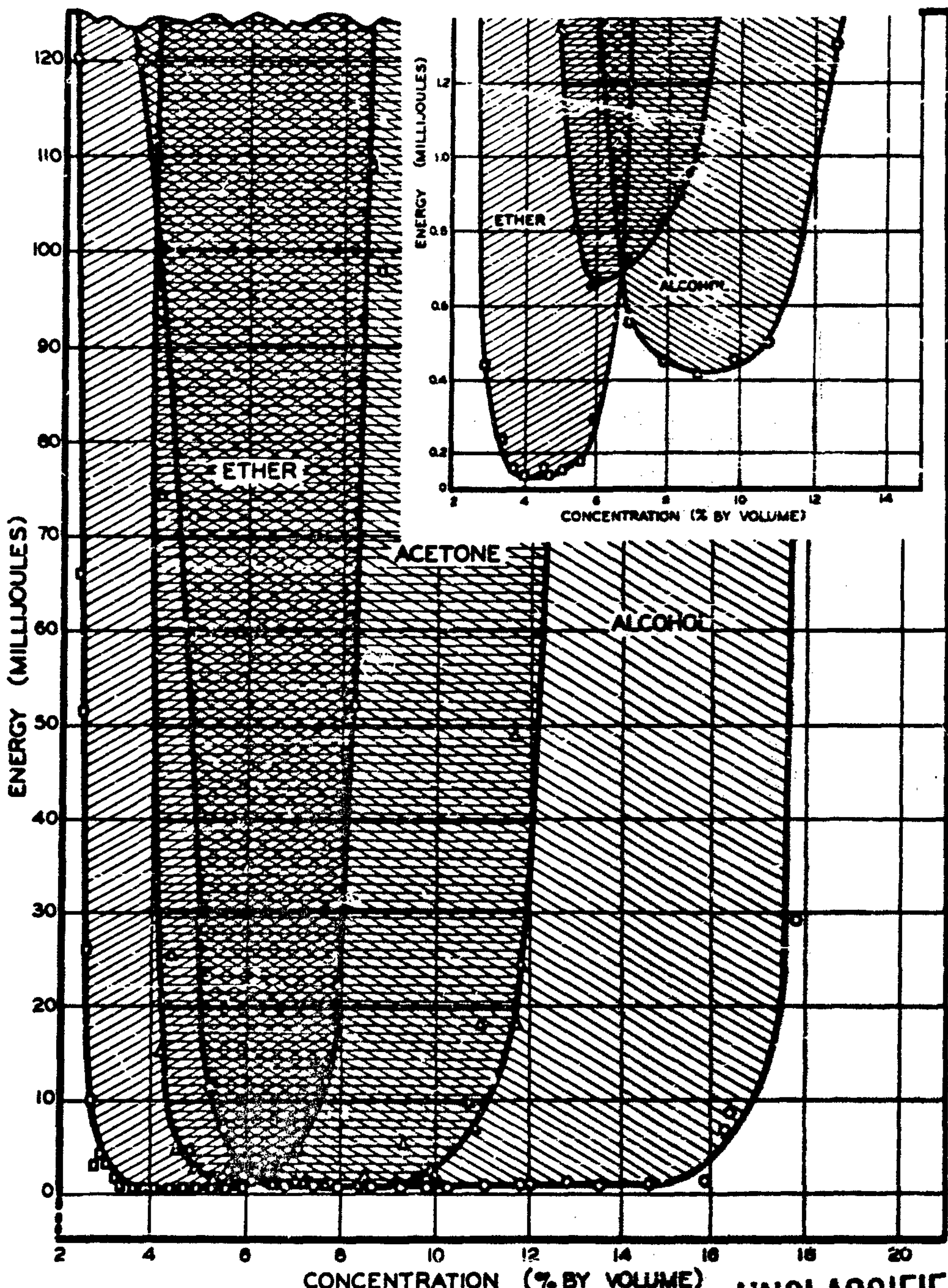


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TABLE E

STATIC POTENTIAL MEASURED ON AN INDIVIDUAL'S BODY

Relative Humidity (%)	Type of Clothing	Type of Insulation	Potential (volts)
17	Wool	Lucite	24,100
16	Wool and Cotton	Lucite	17,200
11	Dynel	Lucite	17,800
11	Cotton	Lucite	12,800
34	Wool and Cotton	Lucite	10,600
40	Wool and Cotton	Lucite	7,515
55	Wool and Cotton	Lucite	990
34	Cotton	Lucite	6,300
40	Cotton	Lucite	2,477
48	Cotton	Lucite	0
		Conductive Shoes on	
35	Cotton	Conductive Floor	0
35	Cotton	Concrete	0
35	Cotton	Wood	890
		Nonconductive Shoes on	
28	Cotton	Conductive Floor	1,635
35	Cotton	Concrete	660
35	Cotton	Wood	1,000

Mr. Paul V. King, Safety Director, Aberdeen Proving Ground: Could you give us the difference between the data obtained with the needle on the plate, on the dust on the plate as compared to the dust laden atmosphere?

Mr. Owings: Without having a number to look at before me now, I would say that they are fairly close together. A dust film can be just as easily ignited as a dust laden atmosphere. If my memory serves me correctly, a minimum ignition energy per dust particle, is .0046 and the minimum ignition level on a film and in a dust cloud, it would be .0096.

Mr. Mack: On your air conveyance work, could you give us some idea as to the relative velocities and relative densities you use on powder and dust?

Mr. Owings: I am not prepared to give that at this time. I have information that I could furnish you on this.

Mr. Mack: We would like to discuss it.

Mr. Owings: O. K.

Captain Jenkins: Can you make it available tomorrow?

Mr. Owings: Yes

Captain Jenkins: Incidentally, Mr. Owings and the gentleman who follows him, Mr. Ballance, both have papers here, which relate to their presentations, which are available to all of you. Thank you very much, Mr. Owings. Mr. Ballance, also a Chemical Engineer at the NPP, will take up the subject of remote processing of casting powders.

Mr. N. B. Ballance, Head, Engineering Branch, Base Grain Propellant Division, Production and Production Engineering Department, NPP:

REMOTE CONTROLLED GLAZING AND SCREENING OF CASTING POWDERS

The majority of the casting powder produced at the Naval Propellant Plant has been manufactured in facilities which were designed and built for the processing of single- and triple-base gun propellants. Whereas some of these facilities are adequate for the production of single-base and double-base propellants, safety considerations and explosive capacity limitations obviate their use for the processing of the new high-energy powders containing nitrocellulose, nitroglycerin, aluminum, and ammonium perchlorate. Additionally, the explosive classification of double-base casting powder has been changed from Class B to Class A. Consequently, a program has been initiated to modernize and/or relocate certain operations that are in the hazardous category. In some cases, the foregoing procedures are not feasible except as an interim measure, and new facilities are required.

To illustrate how facilities are being modernized and converted for remote-controlled operation at the Naval Propellant Plant, I will use the glazing and screening of casting powder as an example.

Casting powder is glazed or coated with graphite for the purpose of polishing, compacting, and rendering the grains electroconductive; the operation is accomplished by tumbling in a copper barrel. The powder is subsequently screened in a Great Western anti-gravity machine to remove fines, agglomerates and oversize material to insure good casting characteristics.

Prior to 1959, the glazing-and-screening operations were conducted in two identical brick buildings located in the Single-Base Propellant Line. Figure 1 is an exterior view of the front of one of these buildings. Figure 2 is an interior view of one of these buildings and shows the typical arrangement of the equipment therein. Figure 3 shows the screening machine. These facilities are no longer utilized; however, the following description of the operations is given for the purpose of comparison with the modernized facility.

DESCRIPTION OF OPERATIONS

After being dried in a forced-air dry house, the casting powder was packed in Mark 24 powder boxes, approximately 150 pounds per box, and transported to the glazing and screening building via rail or truck. The powder was then transferred to a 150-pound-capacity copper container, weighed and manually charged to the barrel. This procedure was repeated until a 1,000-pound increment was obtained, whereupon approximately 160 grams of graphite was added. The building was then evacuated and the barrel was started from a switch located on the outside wall of the building. After completion of the glaze cycle, which required three hours, the operators returned to the building and, utilizing polyethylene scoops, emptied the contents of the barrel into fibre containers. The Great Western screening machine was then started, and powder from the fibre drums was charted to the screen feed hopper.

This type of screening machine used was of wooden box construction and was vibrated by an electric-driven eccentric located on the bottom of the box. Casting powder flowed through the hopper and was distributed

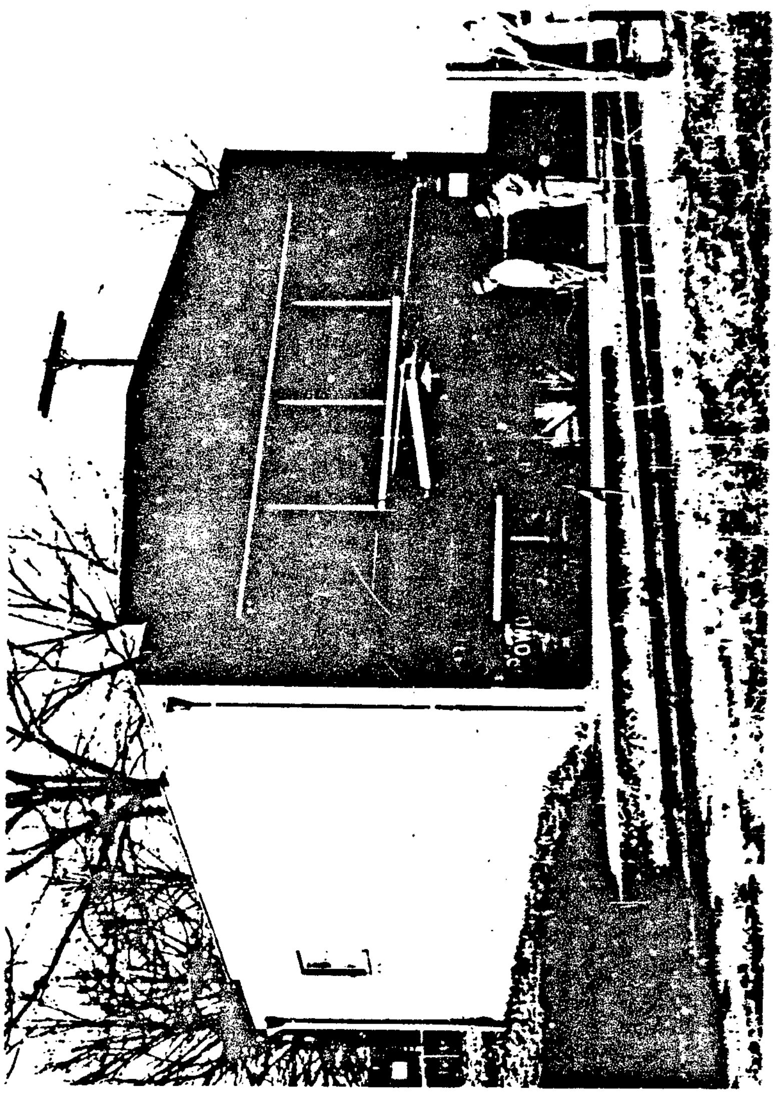

FIGURE 1

BUILDING FORMERLY HOUSING GLAZING-AND-SCREENING OPERATIONS

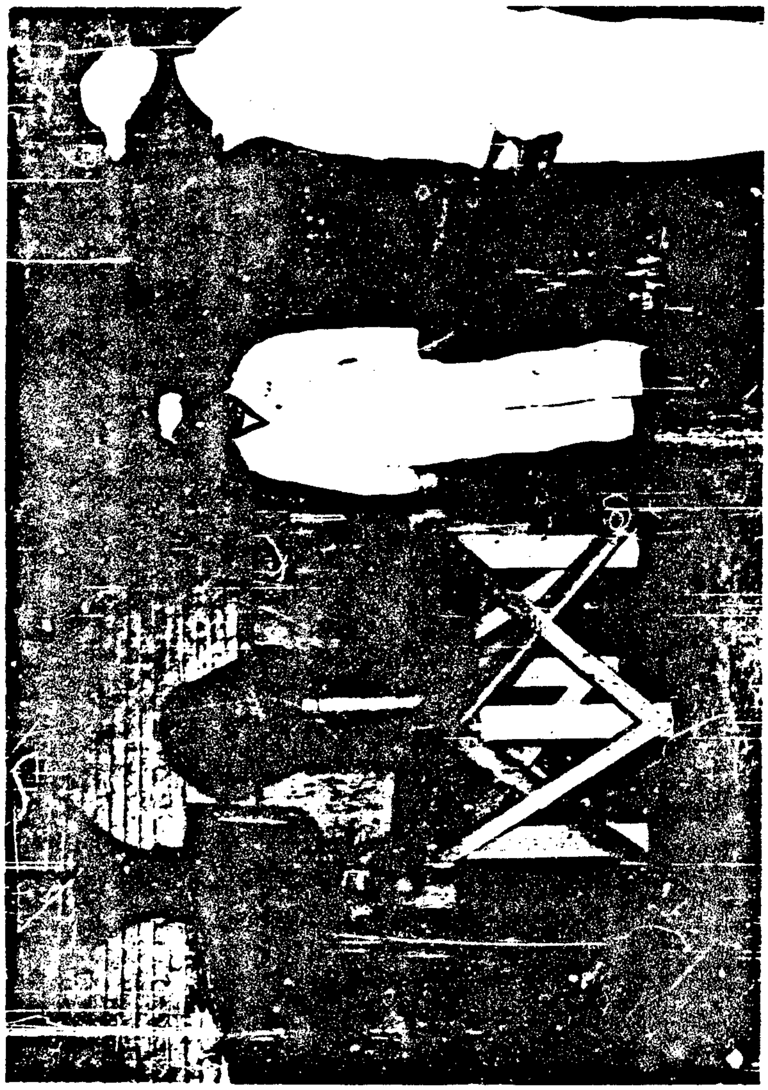

FIGURE 2

GLAZING-AND-SCREENING EQUIPMENT - PRIOR TO 1959

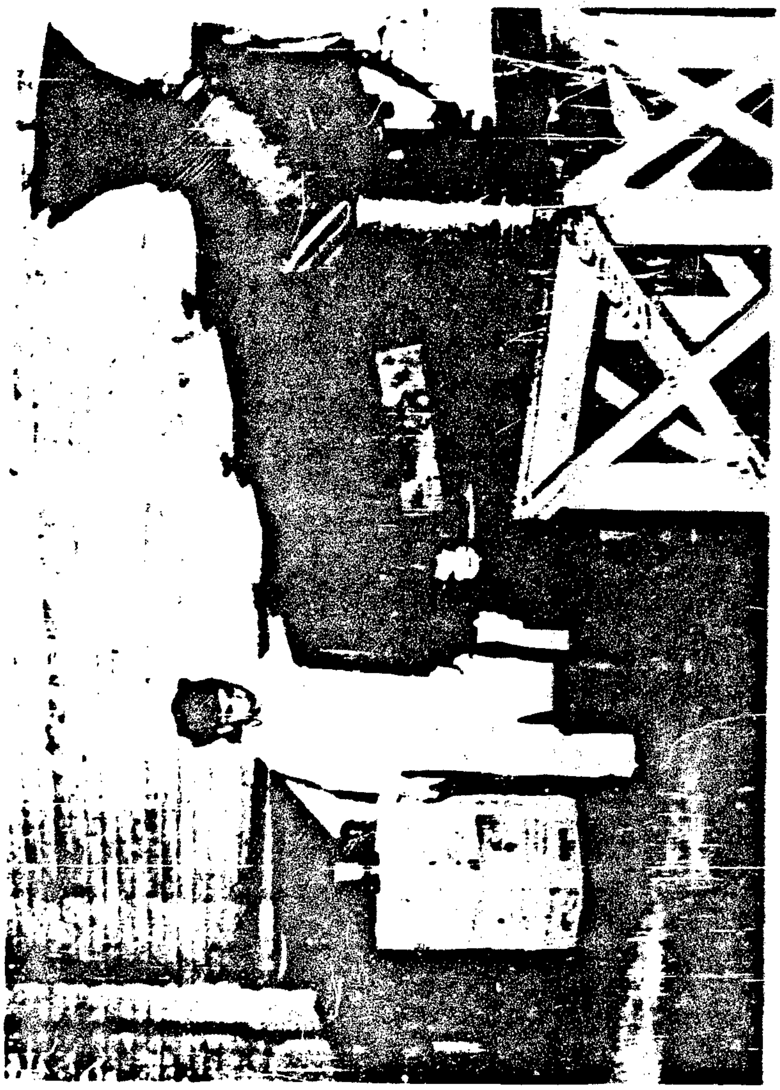

FIGURE 3

SCREENING MACHINE IN USE PRIOR TO 1959

onto the head end of a divided sieve which removed the fines. The casting powder flowed to the tail end of the machine where it passed through the sieve, and the oversize flowed off the end of the sieve. The casting powder, oversize, and fines were discharged through separate chutes at the tail end of the machine and were collected in fibre containers.

After screening, the casting powder was weighed into Mark 24 powder boxes, 150 pounds per box, and transported to a storage point where it was held pending the cross-blending operation. During 1957 and 1958, approximately 936,000 pounds of single-base casting powder, 1,532,000 pounds of double-base casting powder, and 88,000 pounds of high-energy casting powder were satisfactorily processed in these facilities without mishap.

From this record of sustained operation without incident, it might be stated that the facility was adequate safetywise.

However, on 31 December 1958, a deflagration occurred in Building 298 while a high-energy casting powder was being screened. The force of the deflagration destroyed the building, killing two operators and severely injuring two others. Operations were immediately suspended in the remaining building. As a result of the investigation that followed, it was recommended that the glazing-and-screening process be remotely controlled and operated and that the screening machine be redesigned to provide an all welded seamless unit to eliminate pinch points and inaccessible cracks where dust might accumulate.

Although plans were already underway to provide new glazing-and-screening facilities, these would not be available until December 1959. Therefore, a planning group was formed to develop the criteria for establishing an interim glazing-and-screening facility to provide maximum operator protection. The criterion established for the new installation was that all operations involving the flow or movement of casting powder, other than transferring from one operation side to another in closed containers, be performed by remote control.

Building 708, which was chosen for the new installation, is located in the multibase plant, and was formerly used for screening cordite gun propellant (Figure 4). The two-story building is constructed of concrete blocks with a slag-covered built-up roof. The floors are reinforced concrete with spark-proof finish. The first floor has a service entrance at the front, and the second floor is served by an elevator. The rear of the building is adjacent to a railroad, which also serves the second-floor level. This building and the equipment installed therein were modified to permit the following operations to be controlled remotely from a new, reinforced-concrete control house, which was erected approximately 170 feet away.

1. Charging of casting powder to the glaze barrel from a 1000-pound-capacity portable hopper.
2. Operation of the glaze barrel.
3. Discharge of the glaze barrel into a 1000-pound-capacity portable hopper.
4. Feeding of 1000-pound increments of casting powder to a new, locally fabricated screening machine of all welded, seamless aluminum construction.

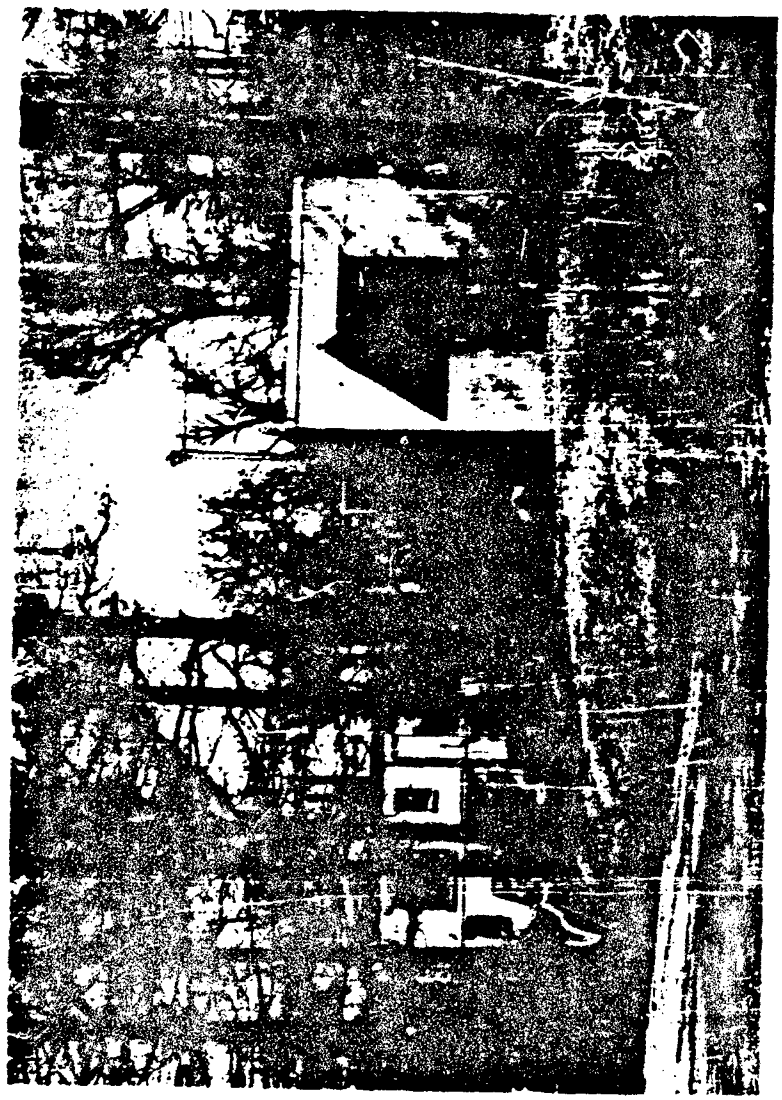

FIGURE 4

BUILDING HOUSING NEW GLAZING-AND-SCREENING OPERATIONS

5. Operation of the screening machine and monitoring via closed circuit television.
6. Collection of 1000-pound increments of screened casting powder into seven Mark 24 powder boxes or a 1000-pound-capacity portable hopper.

The following is a description of the operations currently conducted in this building.

After drying, casting powder is charged into a 1000-pound-capacity portable hopper. The hopper is of welded aluminum construction and is supported on a welded, magnesium-base assembly with four conductive tired wheels. The bottom of the hopper is fitted with a hinged rubber-gasketed closure which opens upon withdrawal of a retaining pin and permits bottom discharge of the hopper contents.

The hoppers are transported to the second level of the glazing and screening building by rail, and are then pushed into the building. The hopper is lifted from the base with an overhead, air-operated hoist and positioned over the barrel (Figure 5). An aluminum funnel is positioned between the bottom of the hopper and the charging port of the glaze barrel. A linkage which is fastened on one end to a solenoid-valve-actuated air cylinder is connected to the hopper closure-release mechanism. The operators then retire to the control house, the solenoid valve is energized, and the powder flows from the hopper into the glaze barrel. The hopper and funnel are manually removed, graphite is charged to the barrel, and the glazing cycle is started from the control house. The operation of the barrel is viewed from the control house through a picture window in

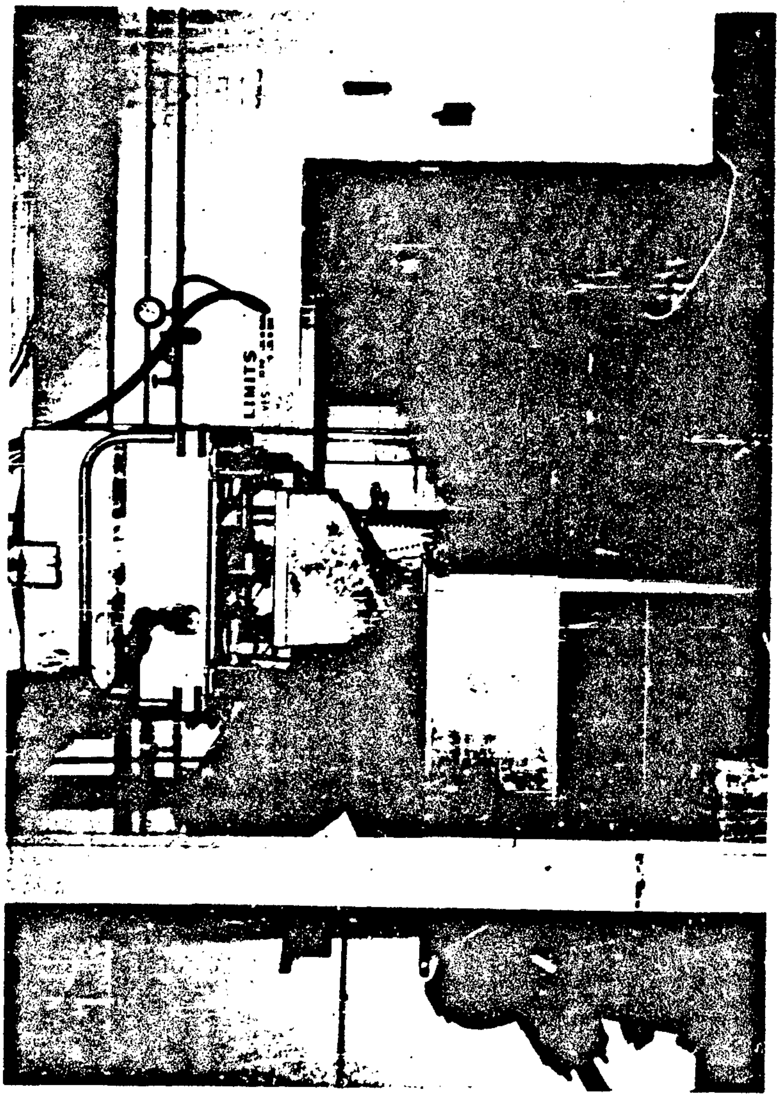

FIGURE 5

HOPPER POSITIONED OVER GLAZE BARREL

line with the barrel - Figure 4. After a three-hour glaze cycle, the barrel is stopped with the discharge port in the up position. The discharge port is opened by manually removing a rubber-gasketed closure. The barrel is remotely rotated until the discharge port is in the down position. A large aluminum funnel permanently supported under the barrel and extending through a hole in the floor directs the casting powder into a 1000-pound portable hopper on the first floor level (Figure 6). The hopper is taken to the second floor via elevator and is positioned over a chute extending through the floor and attached to the screening-machine feed hopper (Figure 7). The release mechanism of the 1000-pound hopper is linked to an air cylinder, and the operators retire to the control house. The screening machine is started, the solenoid controlling the air cylinder is energized, and the casting powder flows into the screen feed hopper. The casting-powder flow rate is controlled by an orifice located on the discharge port of the 1000-pound hopper.

Sieved casting powder flows from the screening machine through a discharge chute extending from the tail end of the machine. Figure 8 shows the arrangement for collecting the powder in Mark 24 boxes. Prior to starting the machine, eight powder boxes are placed in a tray which can be moved along a roller conveyor track located beneath the product-discharge chute of the screening machine. An eight-section multiple hopper is placed on the boxes. After starting the screening operation, which is monitored by closed-circuit television, the operator positions each successive box under the discharge chute by means of a hand winch in the control room which is connected by cable to the conveyor tray.

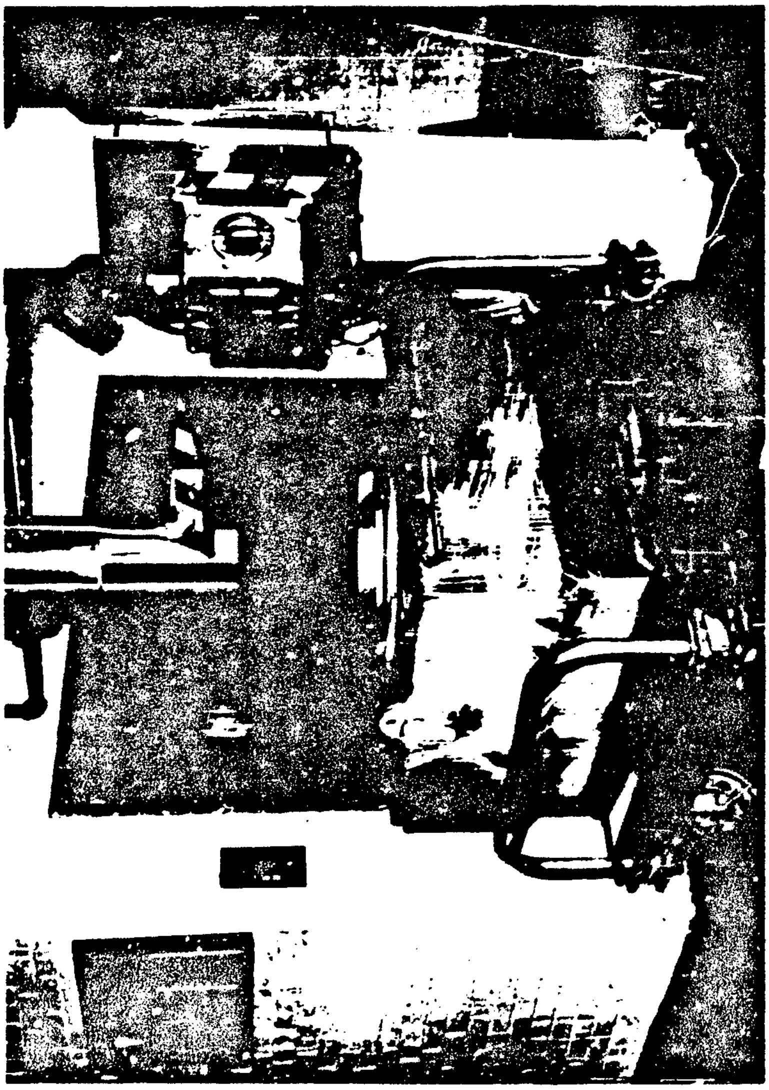

FIGURE 6

PORTABLE HOPPER

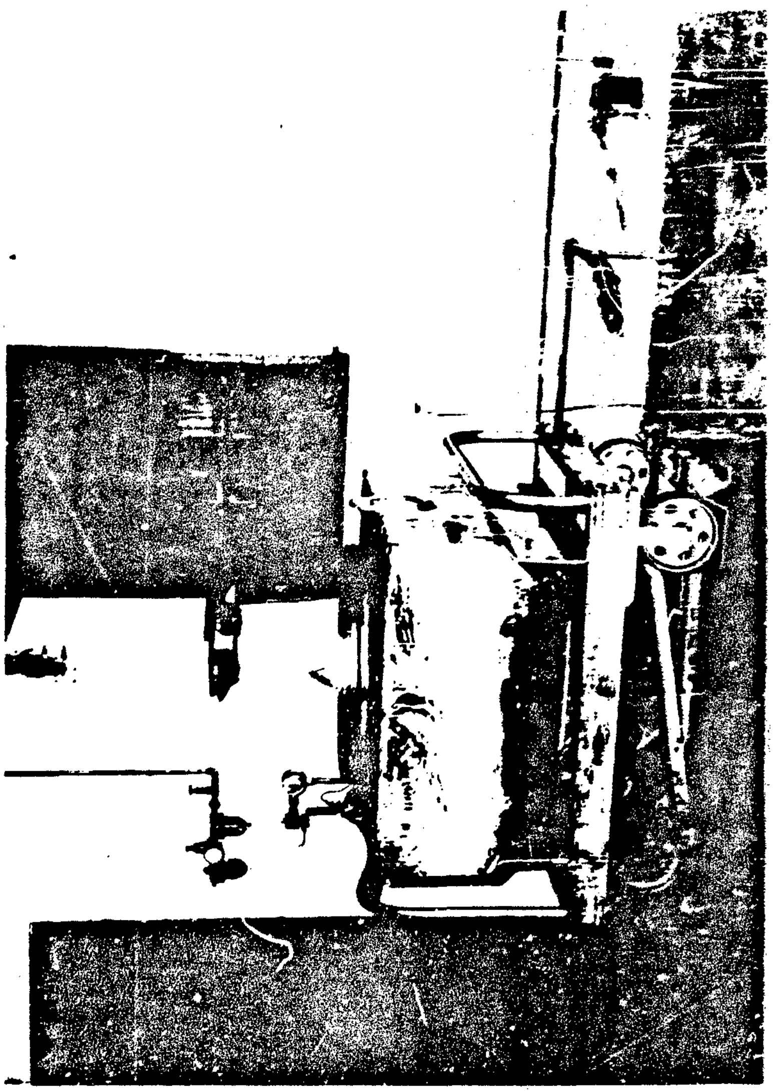

FIGURE 7

SCREENING MACHINE FEED HOPPER

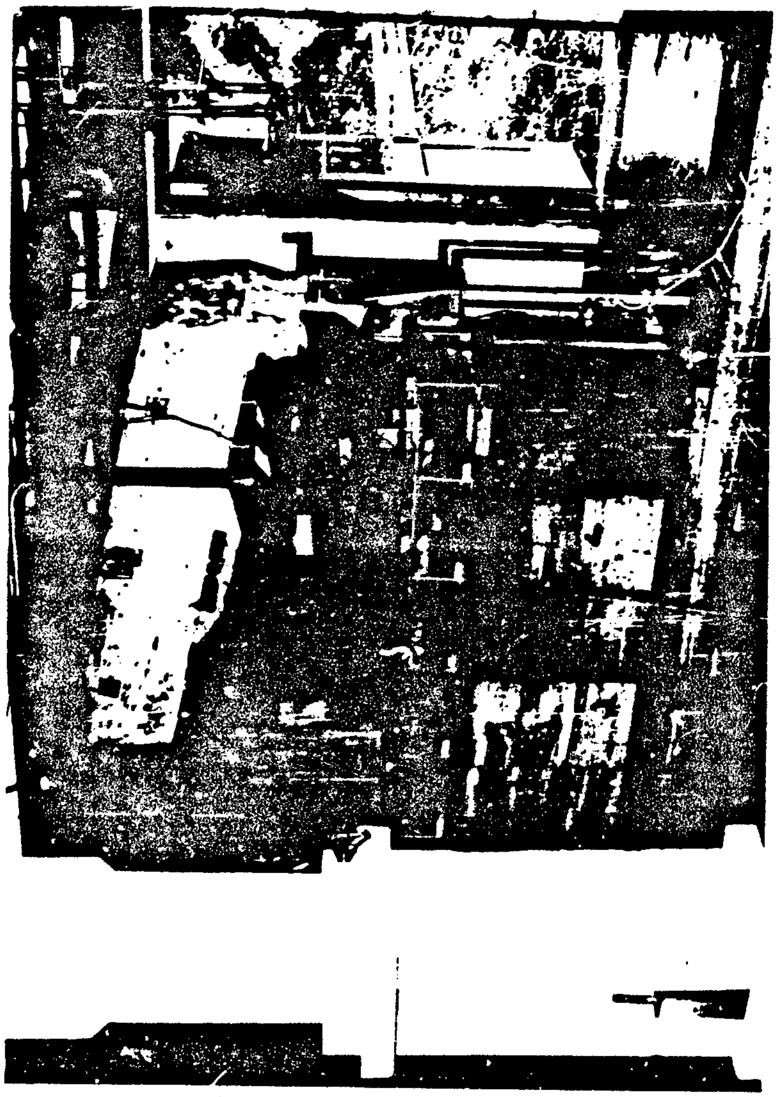

FIGURE 8

COLLECTING SCREENED POWDER

Figure 9 is an interior view of the control house. A microswitch located at the bottom of the screening machine actuates a pilot light in the control room which informs the operator when each box has been properly positioned. The operator knows the approximate time required to fill each box and can therefore reposition the boxes as required. After completion of the screening operation, which can be determined by viewing the screen discharge chute, the screening machine is stopped. The operators then return to the building, install the box covers and remove the boxes from the conveyor. Each box is then weighed, marked, and loaded on a truck for shipment to storage.

This facility, which required approximately 1½ months to complete has now been operated continuously for approximately 3½ months. Although the aforementioned deflagration probably resulted from the operation of a defective screening machine, the introduction of remote control for all of the related operations has eliminated the exposure of personnel to a potentially hazardous source.

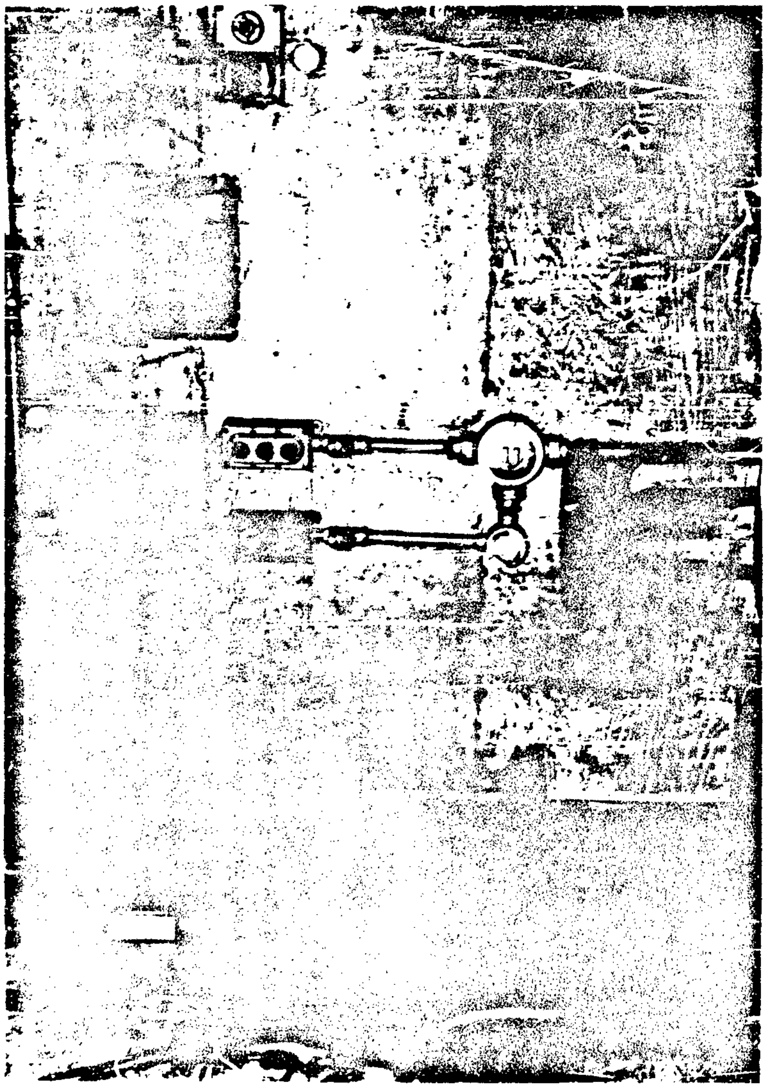

FIGURE 9

INTERIOR OF CONTROL HOUSE

Mr. F. M. Bishoff, Civilian Chief, Intelligence, Security & Safety Office, OCO: Will those deluge nozzles put water into each container?

Mr. Ballance: We have complete coverage for the Mark 24 boxes as they are being filled and afterwards until they are removed from the conveyer.

Mr. Jezek: I have several questions. If you are loading one box at a time, since you have one chute, why do you bring in 6 boxes and load all 6 one right after the other? The other question is: How do you control dust in this particular building? The third questions is: Does the picture window act as a vent or weak wall in this particular building?

Mr. Ballance: To answer your first question, I feel I inadequately described the operation. Actually, 1000 pound increments are charged to the screening machine and the flow is continuous. The discharge is continuous and the collection into each Mk 24 box is continuous until all of the entire 1000 pound increment has been collected. Of course, this is accomplished by this 8 section multiple hopper which is flared at the top to a degree to permit discharge from the chute into the hopper. In other words, say 2 boxes. The box is re-positioned. There is a splitter so to speak which, at some point in re-positioning, splits the discharge from the discharge chute of the screening machine and permits it to flow into the next box. But, the hopper is large enough, and this splitter is low enough to permit this operation without spilling of casting powder on the floor. Another provision to take care of any spillage that might occur is the large pan in which the boxes rest. The picture window would provide a very good venting source. Actually though, the rear of the glaze barrel is painted with two strips, one which is bright yellow and one which is bright red, which permits the operator to stop the glaze barrel at the proper position so he can go in and manually open the discharge port. Then the other bright strip permits him to rotate the barrel 180 degrees thereby permitting discharge of the barrel. You have another question which has slipped my mind.

Mr. Jezek: How do you control dust?

Mr. Ballance: We have a very tight screening machine and most of the dust that is in the casting powder is taken off at the head end of the sieve. We have a single frame sieve in this unit which is divided, the upper portion has openings approximately .028 of an inch dimensionally, and the lower section approximately .062. All of the dust though, in general, is removed at the head end of the screen and by baffling internal baffling of the screening machine, this material settles on out and actually the fines that do come out create very little dust. Of course, the building is thoroughly washed down at least once a week. But, we have not found dust to be anything like the problem that we did experience in the wooden box - screening box.

Mr. Schaefer: The Mk 24 powder boxes that are used, are they copper lined?

Mr. Ballance: Yes, they are.

Mr. Schaefer: And this is a perchlorate casting powder you are talking about?

Mr. Ballance: Yes.

Mr. Schaefer: Is there any concern about this?

Mr. Ballance: We are not very happy about this, but it seems to be just about the only thing that is in existence today. As you probably know, I think Radford has done quite a bit of work on design of a new powder box. I think this is a Harquist container. I don't know whether the tests on the machine have been completed or not, but right now, we are somewhat limited to the Mk 24 powder box and there are relatively millions of them available and this is what we use. At one time, we packaged the casting powder, that which contained ammonium perchlorate, in polyethylene bags. 25 pound increments and placed these in the boxes, but since then we have discontinued the practice, and has, I think then brought out prior to this discussion, I think the real problem that you have with ammonium perchlorate is at elevated temperatures.

Mr. Rochford: Do you weigh those powder boxes?

Mr. Ballance: I left that out. We do, after all of the casting powder has been collected in the boxes, the operators return to the building and each box is weighed and tagged. There is some difference in weight and normally this is well below 5 pounds. Maybe 3 pounds or so.

Mr. Rochford: This is probably not so important at this stage because you have to blend it anyway. Is that right?

Mr. Ballance: That is correct.

Mr. Rochford: The other thing was: Do you have HAD heads or some similar device inside that screen box?

Mr. Ballance: Yes, if you would like to see those. Will you project slide 8 again? I think I can show you those. Here is one which protects the front end of the screening machine and this is the other, and we have another back here. I don't believe I can pick it out. We also have another, by the way, over the 1000 pound portable hopper which is used to collect the glazed casting powder. In fact, each operation is covered by HAD devices and extensive deluge protection.

Mr. Bishoff: I am still concerned about deluge heads. If you reposition these tables do you have additional deluge heads that are not shown in the picture?

Mr. Ballance: There are boxes that are not covered.

Captain Jenkins: It is on the tail.

Mr. Ballance: Actually there is no point along this train in which the box is not covered. I would like very much to show you the building, but it is on the tour, very effective tour which continues, by the way, on Friday and the building is being decontaminated, and I think possibly it might be available for inspection.

Mr. Bishoff: I have another question.

Mr. Ballance: I think I see what you're question is. This box train, by the way, moves down in this direction. In this direction, we have our collection hopper for our glazed casting powder. So we have deluge heads that continue on down the building. Actually, from this point, we have another 20 feet or so behind.

Mr. Bishoff: I notice you have electrical bonding on this set of equipment, but on the previous slide, I noticed no electrical wire connecting the spout from the sweetie barrel to the container that is above the screen.

Mr. Ballance: Is this the discharge of the glazed casting powder into the fixed hopper underneath, or is this the discharge of the casting powder through the hopper and out the chute reaching the 1000 pound portable hopper?

Mr. Bishoff: Into the 1000 pound portable hopper, I believe it was.

Mr. Ballance: Can we have the previous slide? I may explain that this was set up primarily to take pictures. I mean operations were not being conducted at this time, so it is quite possible that, and I see that we do not have a grounding wire. Grounding clips are extensively used in the building and wherever possible, they are permanently affixed.

Mr. D. I. Graham, Jr., Technical Advisor, U. S. Army Ordnance Missile Command, ARGMA: Is there bonding wire between the --

Mr. Ballance: Yes, definitely. I say we do use grounding clips in this operations, and wherever possible, they are permanently affixed. But, as I say, this was set up primarily to take pictures and this was apparently forgotten at the time.

Mr. Jezek: I have another question. Once that flow of powder has started, how do you stop it? What type of valves do you have on your chute to stop the flow of powder?

Mr. Ballance: From the hopper above?

Mr. Jezak: That is right.

Mr. Ballance: We do not. We have a portable hopper which will contain the entire 1000 pound increment.

Mr. Jezak: How about your 6 boxes, how do you control that once it is started?

Mr. Ballance: We don't. We actually let the operation continue until all of the powder is collected. I think maybe I missed you. I said just not continuously, but I associated the word with 1000 pound increments. In other words, 1000 pounds of casting powder is continuously screened until, that is, from the start to the end and we have an extra box in the box train to take care of, say over filling one box, and possibly piling up into the hopper itself. So, we have no difficulty there.

Mr. Rochford: I might clear up one statement on this Harquist container, that is the aluminum container versus this copper liner you have here. The work was completed on that, in fact, the propellant was loaded and shipped around the country to various ordnance installations and the containers evaluated. The only reason they are not in service is they cost money, and actually, Hercules is using those containers in their commercial plant for transfer of high energy base grain from blending to packaging. But, I think it will be some years before they get into the ordnance circuit.

Mr. Ballance: Thank you.

Mr. Wallace W. Burton, Safety Engineer, Solid Rocket Propellant Plant, Aerojet-General Corporation: Two questions. I saw in one of the pictures a load limit on a building of a 1000 pounds, I believe.

Mr. Ballance: That is correct.

Mr. Burton: You also mentioned the spur track and the place for a box car up next to it. What would be in this box car? This is my first question.

Mr. Ballance: We have provisions at this building to either bring the 1000 pound hopper by truck or by rail. Nothing is in the box car.

Mr. Burton: O. K. Secondly, what provisions do you provide for controlling pedestrian or vehicular traffic on that road that you showed us there?

Mr. Ballance: That is another point I failed to mention. This road has been closed, at the entrance on one end and for considerable distance on the other end and is open only to emergency type vehicles. The reason for this is, we have to have access along that road to provide adequate fire protection for some of the other operating buildings, so the road is never used except in an emergency, by emergency vehicles.

Mr. Buxton: I believe that our tour yesterday went down that road, did they not? I just wondered why we did not get into the building.

LCDR Buckles: Yes, sir. The building was shut down when we were out there.

Mr. Albert Gaylord, Project Engineer on Propellant Detonability, Aerojet-General Corporation: I have one question concerning the viewport from your remote control building. That picture window. Why don't you use a periscope or a mirror arrangement?

Mr. Ballance: This is an interim facility. We know that we can do much better. We think that we have our personnel adequately protected at that point. We are sure of this.

Mr. Gaylord: You said you were 160 some feet, I believe, away from the operating building.

Mr. Ballance: Yes, and the walls are approximately 1 foot thick reinforced concrete.

Mr. Gaylord: What about your windows?

Mr. Ballance: Actually, in one of the incidents which we sustained here, the wall nearly failed, whereas the viewport which was directly struck with a missile did not fail.

Mr. Gaylord: Yes, but there are other incidents.

Mr. Ballance: I agree, the viewports are poor.

Mr. Gaylord: Yes, they are.

Mr. Ballance: But, as I say, this is an interim measure and we were in a great rush to get the facility back into operation, and we are planning to start erection and construction of new facilities shortly. These, by the way, will have closed-circuit television for these facilities.

Captain Jenkins: One more question. Mr. Stuckey.

Mr. Stuckey: I don't want to pot shoot this time. I just want to, in fact, I thought that if you got the maintenance men to take care of that thing, I think you would have something. It does point out one thing. I would be willing to bet that the screen failed because it was in bad shape and not because the operation was so terrifically dangerous. I mean I would just be willing to make a bet on it that it was something of that type. Nevertheless, the thing I want to bring out is that, I think when we do have an incident in this plant, in any of these plants, there is too much panic planning. We had a pretty bad one up where I was, and the big job was to keep them from putting in 90 foot thick walls and stuff like that. Because if you put in stuff that is hard to clean and hard to take care of, and put in unnecessary things and

run 2 or 3 years after that without any trouble, you are going to be ignoring all of it and half your program is going to be down the drain. Only thing I'm saying is, when these incidents happen, I believe in taking care of them, but let's don't go too fast and too far with these things. The only reason I brought it up is because there was an awful action taken on this one incident here. I would also like to sound off on viewports, but I won't.

Captain Jenkins: I think we are a little pressed for time here. We can work this one over a bit. If you want to continue to work over Mr. Ballance, take him apart after hours. I would like to get on with the next one. Thank you very much, Mr. Ballance. I would like to emphasize again that he has the viewport paper here on the platform, if any of you would like it. If there are any other questions, see Mr. Ballance later. Dr. Amster, NOL White Oak, Maryland, has a long subject here. Go on, Dr. Amster.

Dr. A. B. Amster, Sup. Chemist, Physical Chemistry Division, Naval Ordnance Laboratory: We have to wait a few seconds while we get the slides ready, so let me say how we had to get around to that long, long title which isn't a title at all. Some weeks ago, the laboratory received an invitation to send a representative. I guess maybe it isn't very flattering, but the way the representative got picked is that I was at the bottom of the heap. The buck got passed as far as me and I had no further to pass it. I am obviously the logical man under the circumstances to go. I said all right, I'll be there. About a week later, a secretary called me up and said, "We have to send in a list of titles, a list of items rather, just work that you have been doing, are doing, and will do." So I wrote this up real quick, and the next thing I saw was a copy of the letter that Dr. Amster would attend the meeting and would be prepared to discuss the following subjects. So the things that are listed, there are some of the things that we have done, some that we are doing, and most that we plan to do. I think also, before I begin what I have to say, of something worthwhile remembering. There was a remark made here before, I forget by whom, that everybody knows how sensitive nitroglycerine is. I had the privilege of seeing some work done by Dr. Winning of DuPont here a while back and I think that any of us who have preconceived notions of what happens with explosives, should also see these pictures. Dr. Winning shows very beautifully how, under certain circumstances, nitroglycerine will not propagate a detonation. Now those of you who raise eyebrows rest assured, my eyebrows went up just as far. But, it was a perfectly reasonable experiment, no tricks. He just took a little bit of care, I think, to get some bubbles out and watch out for rarefaction waves in his detonation, and low and behold, he put a detonator, I think it was an engineers special or No. 8 into a pot full of nitroglycerine and all he did was to stir it around and make it mad. So if we ever get this, while were are talking about this thing, I refer you to Dr. Winning. His pictures, by the way, which are very good, I believe were published in one of the recent explosion symposia.

Is that right, Dr. Shaefer? I think it was in the combustion meeting in England last year or the year before. Also to preface my remark, I should say that these are the results of a research program that such conclusions that I may draw, such remarks that I make, apply to the finished product. I am not concerned even secondarily with the manufacturing processes with which I think most of you gentlemen are concerned. And lastly, before I begin, I should like to point out that a few of the remarks I make are classified. In general, my comments are unclassified, however, the following classified CONFIDENTIAL information relating to the identity of a propellant and its exact formulation, and also I will make some remarks pertaining to the dimensions of the POLARIS grain. These are the only items that are considered CONFIDENTIAL. Please remember that. O.K., now let's get into what I have to say. A couple of years ago, NOL was charged by the Special Projects Office, Bureau of Ordnance, with studying the measure of detonability and of the deflagration to detonation transition which we periodically call DDT -- if I use these terms you will know what I mean -- when i. e. studying these phenomena in solid propellants. As a consequence of this we have examined methods for measuring the detonability and we have measured the detonability of a number of materials. I think I might emphasize here that when I say detonability, I mean detonability as distinguished from explosion. Much of what I say here is a summary of information which has been recorded elsewhere in much greater detail. Those of you who are interested, you will find that we have a number of NAVORDS from the laboratory, NAVORD reports. The last two JANAF SPIA meetings, and I also believe the last two surveillance panel meetings have reports on the material covered here and also the sensitivity conferences at NOL. Material was published two years ago under the NAVORD title, and most of the information is already in there. Well, to get into the meat of it, experience with explosives had led most people to recognize that which is true that there is a correlation between shock sensitivity testing and impact materials. This, unfortunately, is not true for propellants. Now let's see if we can't str[illegible] the lights on, with these slides. We might just be able to get [illegible] I think we will. There are no photographs here, just line drawings. Is this legible back there? Well, let's leave the lights on. I don't think there are any...What I have here is an approximate order of impact sensitivities for some common explosives and propellants. These impact sensitivities are run on a standard Bureau of Mines test by some statical fashion up or down, back or something. In the left column I have listed some common explosives ranging from PETN and with an impact sensitivity of 11 to 16 centimeters, through RDX and tetryl 26 to 50 Composition B 85 to 82 down to TNT with an impact sensitivity ranging from 150 to 215 centimeters. Materials from PETN down through tetryl as being certainly not high explosives, but boosters and in some cases, primary compounds. In the right hand column I have listed the impact sensitivity of a number of propellants. Now ammonium perchlorate - aluminum powder propellant with petrinacrylate has a sensitivity of 11 centimeters, polysulfide rubber propellant impact sensitivity 15 centimeters.

A nitrosol propellant from NOTS - 18 centimeters. A number of ammonium perchlorate - aluminum powder with polyurethane, polyvinylchloride, or polyesterstyrene mixtures impact sensitivities ranging from 16 to 41 centimeters, finally a double base propellant, in the case I think it was AHH ranging from 28 to 51. Now the interesting thing here or the thing we like to preach, is that all these propellants perhaps including the least sensitive double base, 51 centimeters, all of these propellants are more sensitive than all the standard military explosives, and if we had used a guide for selecting the propellants, that we were going to do further investigations into, we would have been left with none, because all of these things, as I say, are more sensitive than standard military explosives. Well, let's see. In this group here, the ammonium perchlorate - aluminum powder-polyurethane, they were running total solid content about 82 percent. Some of these were run without aluminum powder, just ammonium perchlorate in which case we had 78 or 80 or 82 percent ammonium perchlorate. Now I might point out that in particular well, generally, with one exception, generally these things were run in an unground state. However, we did do some work to see if the physical state had any effect. Now on the polyvinylchloride propellant which is an Arcite 358 I believe, we ran lathe shavings. We ran a number of different types of samples. It didn't make any difference, which is another point that is worthwhile bearing in mind. The state of the sample doesn't seem to influence the impact sensitivity very much. Well, we decided that in order to measure detonability, we had to go right ahead and measure detonability, but impact tests which were, of course, much cheaper and much quicker would not answer our needs. So we modified a gap test which had been in use at NOL. Those of you who are not familiar with this, I will describe it. We have a sample consisting first of all, of a pair of tetryl, well, at the bottom we use an engineer's special detonator, more recently a seismic detonator from Olin. I don't think this makes much difference because either one is generally successful in initiating the tetryl which is consisting of a pair of pellets 2 inches in diameter, each one inch thick, so we have a cylinder 2 by 2, totaling if I recall, about 135 grams of tetryl. There are a number of cellulose acetate cards here. I will come back to this in a minutes. And finally the sample to be examined which is confined in a steel tube of approximately, well, it's a shade under 1 and one-half inches in diameter and about 3/8 of an inch I think, wall thickness at the upper end of the charge, we have a mild steel plate, 4 inches square, 3/8 of an inch thick. The sensitivity of material is recorded in terms of cards or inches of gap returning to the cards here and with a simple statistical fashion they are reported in terms of inches of gap at which there is a 50 percent probability of the material detonating. Now detonation is determined by examination of damage done to the steel plate. In general, it is a very simple matter to determine whether or not the sample has detonated. The detonation cut a great big hole you could send a truck through. If it does not detonate, the plate is relatively undamaged. There is no serious damage to it, although there are exceptions to that. The dimensions of this test were so chosen that first of all, the increase of the donor of the booster is tetryl. Increase in the size would not increase the probability of detonation. In other words, we are giving this thing

the biggest useful wallop that we can with this diameter. The length of the charge, $5\frac{1}{2}$ inches long is so chosen that the damage sustained by the plate is determined by the receptor, and is unaffected by the donor. These tests have been run on a variety of samples under a number of different conditions. Results are summarized on this next slide. Can you lift that up just a little bit, please? For those of you who can't see it, what we have here is a sensitivity in terms of inches as a function of temperature, degrees F. These are gap tests. For OGK, a relatively low energy I guess, double-base propellant, the solid material - the solid does detonate at any temperature of about 10 degrees F. and the maximum sensitivity which does increase with temperature does not seem to get over about .15 inches. I might point out, by the way, that Composition B runs at about 190 cards, tetryl runs up about 272 sensitivity. You will find that the sensitivity increases roughly proportionately. Well now, we use 2 different kinds of pores here, in effort to find out if it made any difference. -- material containing connected pores, the way we made these samples was just to take the little granules which the people down here at Indian Head very kindly prepared for us. We poured them into cubes. And from material containing connected pores, I guess the upper curve is invisible but it doesn't make any difference, it is the same as this, the sensitivity increased somewhat with temperature -- slight dependence upon temperature. Tritonal which is the lease sensitive of the military explosives runs about 110. Now this is on the solid OGK. We start introducing pores into it, we find out that, well, for example, ambient temperature, if we introduce pores to the extent that the material is only 91 percent of the manufactured density, we have increased the sensitivity to a point where you are about 70 cards. If you increase it to about 56.3 percent of the manufactured density, you are up to a point where you are more sensitive than Composition B, and at somewhat more porosity; that is, increased as we had with the solid material. On the other hand, these people here who also prepared for us the sample containing non-connected pores, which is a spongy-like material, we found a rather unusual effect. That is, that the temperature dependence was the inverse of what has been experienced with connected porosity. The material became very, very sensitive at low temperatures and as you increase the temperature, sensitivity dropped. The chart here is a little misleading, of course, because certainly the change in density is going to have some effect. However, it is very interesting that with the material having this high a density, you can still get a very, very sensitive sample. Well, first of all, for any given type of material, as you increase the porosity, the sensitivity increases and it increases very remarkably. We have had some samples of propellant which are normally non-detonable in the solid state and in a porous state they will be as sensitive as tetryl to shock. So the point I am going to make here is that from samples containing connected pores, the temperature dependence is just about the same sort of thing as we get for the solid

materials. A slight temperature dependence. Not much change with temperature. However, when we deal with a double-base sample which contains non-connected pores; i.e., small bubbles, so that the propellant resembles a dense foam, one might say, this material at very low temperatures, seems exceedingly brittle. We have a feeling, quite certain, matter of fact, that this increased sensitivity is due to the very remarkable brittleness of the sample at these exceedingly low temperatures. That answer your question? This particular curve, we had maybe 8 or 10 or 15 points. It was a large number here, for the solid we tested at zero at 25, at 75, at 125 and 150 and I think we tested about 4 or 5 samples here. The data fits it just as well. We also tested the sensitivity of a number of composite propellants. The results were rather interesting. Remember, if we refer to the impact test, here is something worth bearing in mind, that all of the composites that we tested were more sensitive to impact than all of the double-base propellants we tested. Here we find the reverse, in the gap test which I just described, the diameter is up to one and one-half inches, ammonium perchlorate - aluminum powder propellant containing either polyvinyl chloride, polysulfide, or polyester styrene did not detonate. We tested one sample containing ammonium perchlorate, potassium perchlorate, aluminum powder and polyurethane, as a matter of fact, this was one of the early candidates for the POLARIS Missile. We tested this with a seven inch diameter, it did not detonate. We found pieces of propellant left after each of these tests. Finally, in one samply twenty inches in diameter (I will have a little bit more to say about that shortly), one sample twenty inches in diameter which was, these tests were run on the two current candidates for POLARIS. These materials did not detonate. These latter charges were run in order to find out if the full size POLARIS could be detonated, and twenty inch diameter is very closely related, when one allows for the steel confinement that we used, it is very closely related to the web diameter, web thickness in POLARIS. I would like to say a few words about this last charge. There was a question raised some time ago about how one can test the full size missile. This is how we decided to do it. We did not test the missile, we related our charge to the web thickness of POLARIS. These tests I am about to describe were run in conjunction with Aerojet and NOTS. Mr. Gaylord, who is here, was out there with us. We had a sample that was twenty inches in diameter including one-half inch steel tubing confinement. It was eighty inches long. These dimensions were chosen, the eighty inch length was chosen the same as for our gap test so that the effect of the booster would not determine the damage. The booster itself was a cylinder which was twenty inches in diameter and forty inches long. Here again the criterion was that any increase in the size of the booster would not reasonably affect the probability of detonation. On each of two propellants ANP 2639 AF and ANP 2655 AF, which are still the POLARIS propellants, we ran tests in duplicate at minus seventy five, at ambient, and one hundred eighty degrees F. In no case was there any evidence of a detonation occurring. However, we used ionization and pressure sensitive probes at the far end of the charge, away from the booster. This information indicated a high

probability that the propellant had contributed to the substance shock. We made some air blast measurements to determine the amount of damage one might expect after allowing...making correction for the damage done by the booster we came up with a TNT equivalent of a weight of 25 to 100 percent depending on the type of instrument that you used, and I think perhaps the manner in which you interpreted the data. The air blast measurements must not be taken too literally. However, it is quite obvious and certainly by examining the site, it was apparent that the propellant was contributing to the damage that was done and might contribute in similar circumstances elsewhere despite the fact there is no detonation. Well, now what happens to composite propellants when you have a force present? Would connected porosity effect the stimulative effort of a double-base propellant? The sensitivity increases remarkably, there is some temperature dependence, this is the second order of detonation. Rather surprisingly, however, in non-connected pores, the samples are non-detonable. Now you remember with the double-base propellants I pointed out that not only were they detonable but the sensitivity increased very rapidly to a very high level at low temperatures. With the composite propellants containing non-connected pores, we have not yet been able to detonate any of these materials again in the one and one-half inch diameter charge at temperatures down to and including minus two hundred and seventy four degrees F. I think that is approximately liquid nitrogen, which is really what we used. I think perhaps if we got to lower temperatures these samples would become detonable, I am not sure. So we can question the reaction rate of these materials. At these low temperatures it may be so slow that despite any physical breakup we get, the reaction will not proceed. Finally on the ..., well not finally yet, but on the matter of propellants with high energy binders, I think there is some rather revealing information. Here again we have a chart of sensitivity gap test in terms of temperature. This is the data we had before for OGK double-base propellants. Most of our composite propellants were non-detonable, this again was on a small scale test. We have tested a pair of propellants containing petrin acrylate. This, I believe, is the propellant known as PHD. This is the one known as QR, and don't anybody ask me what the formulas are, I forget, there maybe some gentlemen here who do remember. Notice now through, for example, this propellant at ambient temperature about seventy five degrees, this material has a gap sensitivity...obvious [illegible] somewhere.. but it has a gap sensitivity of about [illegible] which is just a little bit less than what we were getting with explosives. The nitrosol propellant at the same temperature is a little bit more sensitive although the data aren't here, we have tested the double-base hybrid sort of thing. I think they are being made here. I know ABL is making it. CMF I think is a formulation currently being considered for POLARIS. This has a sensitivity of approximately in this same range, from what I can recall. Work is continuing on these materials as soon as new materials are made available. I would like to enter a [illegible] here, that if any of you who have new propellants that are more than idle curiosity and you can furnish them to us in lots of a few pounds each, let us know and we will see if we

can't make some arrangements to do some gap testing on them to fill in some of the gaps in our information. Most of the rest of our program is far more fundamental in nature. The information I have just been discussing has come largely out of an exploratory program. When we first got into this we didn't know whether the propellants would or would not detonate, depending upon whom you spoke to, you got a different set of answers and we just had to go out and try to evaluate them. This is the way we got our..no I am not ready for this one yet. We have, however, now that we have a feel for this information, a feel for the problems, we have been running into some fundamental problems which we would like to think will, when the programs are completed, permit us to predict the sensitivity of propellants. Now the tests that we just ran on twenty inch diameter charges, you can bet your bottom dollar, they were not cheap. I think just the transportation alone bringing people back and forth from NOL to NOTS and people from Aerojet and so on, just the paperwork ran into some ten or fifteen thousand dollars, and I forget how much the charges cost. Al, do you remember how much that operation cost us? I think the whole business, I think about $50,000 for the charges, or something. Well, all right, at any rate, the point is it is a big number and if somebody can sit down with some small charges and in an afternoon get data, either by paper or by some small tests, get the data as to whether a large charge will detonate, obviously this is going to be desirable. Well, this is the kind of program we are involved in, whether we get results or not I don't know. Among the things we have been investigating...developing, and devoting quite a bit of time to, is the phenomenon associated with shock initiated in a deflagration-detonation transition. Among the things we have done, we have developed techniques for the continuous electrical measurement of shock velocities. Most of this work has been done in the past with cameras. Cameras are expensive, running thirty to forty thousand dollars each. They tend to be a little bit fragile and there also is the disadvantage that you can't watch an opaque charge. All solid propellants I know are so far opaque. The method involves the wire parallel to the axis of the explosive or propellant or instrumentation, which is remote, monitors the position of the ionization which is associated with the shock wave. From these data we can calculate detonation velocities. We can also use the same technique to study the build-up to and the decay from the stable detonation in particular the build-up to stable detonation we expect to get some very interesting information as to the processes which precede the establishment of a detonation, the requirements which are necessary. For example; we already feel that non-defective propellants, even those with energetic binders will up and burn to detonation in the confinement now envisioned; i.e., rupture strengths of about 1000-1500 psi, though we don't design any large scale production on this basis, we certainly feel that the detonation in most of the propellants but not all, most of the propellants which we are considering or which are being considered now, detonation is very unlikely unless you have some very close confinements. It seems almost certain that to have a detonation, one must have present very

high pressures, the sort of pressure that cannot develop, that probably cannot develop by self-confinement of either the propellant or the propellant within a thin walled case. Also we hope these studies will permit the formulation of methods for prediction of sensitivity and of critical diameter. Now this critical diameter is the something that Carl Boyd here said I would talk about, so I guess I have to. I hadn't planned on it, although we are conducting a program of measuring critical diameter, and perhaps of correlating this information with others. For those of you who may not be familiar with the language, let me define the term "critical diameter". For any material... it is probably true that for any material and certainly for any explosive or a propellant, there exists some diameter below which the material will not under any circumstances propagate a stable detonation. Above this diameter it becomes progressively easier for a detonation to propagate. It seems most reasonable that this critical diameter which is the thing, of course, we were trying to measure in 20 or 20 inch diameter charges to find out if that diameter was above or below the critical diameter -- seems most reasonable that this critical diameter is going to be related in some way of the thermo dynamical or kinetic factors that one can measure in a laboratory scale. For explosives, one can measure critical diameters very easily. They are in the range of fractions of an inch or an inch at the most. Perhaps the correlation for explosives can be extrapolated to propellants. We don't know. We're trying. This brings us to another study that we are conducting. The study of the propagation rates of non-reactive shocks in lucite. Now you wonder what in the "blue blazes" does that have to do with propellant sensitivity. Well, there are two things. First of all, lucite simulates very nicely the properties of a propellant at low temperatures. At least as far as the plastic binder is concerned except that the shock propagation in lucite and shock propagation in a propellant, any increase in shock velocities or decrease in the rates in which shock decay, we feel can be attributed to the measure with which the propellant contributes to the shock rate. This in turn is a measure of the sensitivity and perhaps can be correlated with critical diameter. More interestingly, I think, at least for the moment, and perhaps more practical, is the fact that the lucite simulates very nicely as a matter of fact, is inch for inch identical with the cellulose acetate cards that we use in our gap test, so that if we watch the behavior of the shock in the lucite we will know precisely how it is behaving in the card gaps. We have taken information of this sort, I won't bore you with it, and we have coupled this with some information available from the Atomic Energy Commission, our own detonation division at NOL and from some British information made available by the Ministry of Supply correlation of shock and particle velocities in lucite and with this information, combining with our own, we have been able to estimate the pressures which are required to initiate detonation, pressures in a shock wave, that is, that are required to initiate detonation in an

explosive or a propellant. Now these data have been translated in terms of our gap data and finally, we are able to say as on this next slide, a given propellant or explosive has a sensitivity of such-and-such a gap; therefore, what we are really saying is that the pressure which is required in a shock wave to initiate detonation has such-and-such a magnitude. These data are preliminary. They are not very precise. I'll give you an order of magnitude of precision but before we go into this, let's look and see what we have. Look at Composition B with a gap of about 180 cards or 1.8 or 1.9 inches. We find that a pressure of approximately 20 kilobars is necessary to initiate detonation. This figure is probably off. It is probably closer to 30 or 40, but at any rate, these are order of magnitude figures. The precision can be estimated by the size of the bar on the curve at the point where you read the ordinate and you notice incidentally if you get up to propellants, our precision increases. There is a good reason for this, by the way. Composition B is a pretty sensitive material and notice as we slide up this curve, the pressure goes up rather rapidly until we get up to, let's say, the nitrosol propellants where we need something of the order of magnitude of 50 or 60 kilobars of pressure to initiate a detonation. That means, of course, that though these things are detonable, it takes a great big shock to induce a detonation. We are, of course, going to continue these studies. Lastly, in the programs under investigation, we have been investigating the thermo-sensitivity of propellants. We are looking into the relationship between thermo-chemistry and the chemical kinetics in propellants and explosives and trying to correlate this in some way with sensitivity. I am not sure how we are going to do this, but there must be a correlation of some sort and we hope to find it. We use a rather well-known adiabatic self-heating equation, and as Paul Boyd pointed out to me, I think there is an error in this cube - the heat produced per mole - it should be per gram per unit time. I don't think any of us will let that worry us. The experiment which is performed (and, by the way, these measurements have all been done at the National Bureau of Standards under contract to NOL) consists of a rather refined modification of the usual test we have of taking a hunk of stuff and dropping it into a Wood's bath. We take a piece of propellant of definite dimensions and what we have been using is a cylinder two inches in diameter and two inches long. We put it in an oven with temperature controls independent of adiabatic. The way we do this is to put a thermocouple in the heart of the propellant and a thermocouple in the oven, and as the propellant - which decomposes exothermally - heats up, the oven is made to heat up to 0 so there is a minimum temperature difference between the two samples. The relation we get is:

$$\log \frac{d\ \text{Temp}}{d\ \text{time}} = \log \left(\frac{QZ}{c} \right) - \frac{ET}{R}$$

Q = heat produced per mole per unit time

Z = "collision factor"

c = heat capacity

E = energy of activation of the material

A plot of the data, therefore, as the log $\frac{dT}{dt}$ versus the reciprocal temperature should be linear. The slope should have a value of $\frac{-E}{R}$. The intercept should be $\frac{QZ}{c}$. Here we have some data on which we have done experiments of this sort. On three propellants - AHH, Arcite 358, and Aerojet ANP 26 39 AF we have plotted the log $\frac{dT}{dt}$ against a reciprocal temperature. Encircling other temperatures shown, with the exception of the Aerojet propellant, the data, at the more elevated temperatures, are quite linear. Certainly, in the case of the AHH, they say linear down to fairly reasonable temperatures. You ask "What good is this?" Well, I think on the next curve I can show you. It is possible by using interpretations and solutions of the heat equations which I have shown and upon certain assumptions which I will describe in a moment, to calculate what we call the "critical diameter of a sphere". This critical diameter is for a given temperature of that diameter of a sphere which will explode at infinite time. To put it differently, if the calculations are correct - and this is a big "if"- we can say "Don't store a sample of this propellant above this size at this temperature. It will explode." The assumptions are, first of all, that the data are good, considering the usual assumptions of experimental error; however, I don't think we have to worry too much about experimental error in these problems although, of course, it is real. Then, there is perhaps a far bigger assumption - in particular, with the Aerojet propellant which is a variable one - as to whether the data apply at the low temperatures. Apparently, from the data on the Aerojet propellant and perhaps on others, they do not apply. We must remember, however, that if the sample is allowed to heat, it will heat up to a high enough temperature so that the data do apply. So, these results shown here are certainly an approximation - not a good approximation but worth bearing in mind. To give you an example of the sort of results we got, AHH at 100°C, 212°F, is the critical radius of 10 centimeters. Even if this is in error by several factors of two or perhaps an order of magnitude, we still don't recommend storing AHH at 212°F in big samples. We hope to be able to improve upon these data. We are continuing it with certain explosives to see in what way we can correlate this information with shock sensitivity. That concludes what I wanted to say except for one point. Undoubtedly, as solid propellant becomes more energetic, it will behave more and more like explosives. I don't think that there is

anything we can do about this. On the other hand, I don't think we need to panic since we have been living with explosives for a long, long time and I think we can learn to live with propellants if we remember to respect their limitations. There is another point I meant to mention at the beginning and that is, in using our own pack tests to screen samples of the final work going on in a laboratory, it is fitting to remember that the results indicate an order of magnitude of the hazard. However, by all means, let's not reject a prospective sample merely because it has a high impact test because if we followed this criteria in the selection of the propellants we now have, we would not have any propellants. I think that is all I have to say, for the moment.

UNCLASSIFIED (End of CONFIDENTIAL portion) CONFIDENTIAL

Captain Jenkins: Thank you very much, Dr. Amster, for your presentation. How many would like to ask questions? Since we are a little overtime now, I think we should end this session for today and begin with the question period the first thing tomorrow morning. Also, perhaps some of you would like to question Dr. Amster privately here or, on unclassified material, over at the reception.

(End of first day's session)

Captain Jenkins: Dr. Amster said he would be a little late this morning, but would arrive about 9:30 so we'll go ahead with the next agenda item and take up the question period with Dr. Amster later. The next agenda item is a presentation by Mr. Geoffrey Robellard from the Jet Propulsion Laboratory of the California Institute of Technology. Mr. Robellard has not arrived, and so far we have had no word. I certainly hope nothing serious happened. During informal discussion with other people here, Thiokol and Aerojet have kindly consented to "take on" this discussion this morning on the design of equipment for dust removal and collection and disposal of propellant scrap. Mr. Stuckey, of the Safety Division, and Health Engineer of Thiokol, will begin. Mr. Stuckey, you will be followed by any other people you have to add information to what you present. Then, Mr. Buxton, Safety Engineer for Aerojet, will, with his people, take up the subject.

Mr. Stuckey: I don't have any notes so I may include other that are pertinent to the matter. The first this particular subject I would like to go over rather swiftly because I have no idea exactly what Mr. Robellard intended to present. Actually, in our own business, we found propellant dust and scrap collection quite a problem. Dust removal is a problem in getting the explosives dusts, especially fines, away from some of our operations; for example, [illegible] cuts by sawing and things of that type. We use vacuum in most places at the present time. We would like to consider milling cutters or things of that type and actually design a draw-off system to draw off

the fines, especially for some of the new grain cutbacks that presently require four, five, or even six steps of cutback because of the shape of the grain. These get to be quite a problem. The problem immediately comes up in propellants - whether you are going to use a vacuum or not - if you are going to use a dry system or a wet system - even though today many of our propellants have quite large amounts of aluminum in them, most of our plants collect wet. I'm familiar with the "Protoclone" and "Hoffman" systems - actually, we use a small unit that just sits on top of the drop. I worked in a plant where we handled billions of pounds of aluminum and tritonal and I don't quite have the fear of aluminum that many people have. We had no great incidents in it, although I will say this for it - it takes a little heat. We sent it to the burning field, for example, under water, lots of it. Damp, it seems to work fairly fair. In our other operations we try to emphasize that scrap containing propellant should be removed right after the operation. It is not left in the building overnight. All cured scrap is taken to the burning field under water. One of our divisions puts scrap in cellophane bags and puts water in that also, although most of our divisions take their uncured scrap, heels etc., out dry. At the burning fields we have the same setup as we had in Ordnance in some of the regulations that we follow. In the layout of train of material, we don't pile it up too deep and we take special precautions not to put our oxidizer in with the propellant. Waste oxidizer is quite a problem. We try to burn it and don't have any luck with it. We have a normal practice now of mixing it with sawdust that we use to scour our mixers and we dispose of it fairly well in that fashion. I think our biggest scrap disposal problem is in disposing of it when it is in a piece of equipment or in reject engines or something of that type. The three methods we have tried are burnout, soakout, and mechanical cut-out. There is little to be said about each type; I guess it depends on how you feel about it. In burning out engines, we have tried both underwater and dry, and we prefer the underwater burnout. For small engines, we actually burn them out in drums full of water, with the drums sunk in the ground. We hold the engine at the top and burn it out. For engines that are open in both ends, that are just tubes, and we are not trying to salvage the case, we burn the engines out holding them horizontally on the ground. Either method is a very nice way to handle it although, as I said, we prefer underwater burnout. It has been very satisfactory and the cases have been good. In fact, they are acceptable to Ordnance - certain types of them anyway. The only problem we have had with it is "shunting" (I don't know what you call it). That is, if you don't use a nozzle or some kind of restricting setup over the end of the engine, you get unsteady burning. If your disposal area is close to the plant, you have quite a problem shaking things up a little bit. That can easily be taken care of by a light nozzle of some kind. We have done a lot of soakout also, especially on the composite propellants. We have practically a standard soakout material for polysulfides. It is methylene chloride, xylene mercaptan, 90% by volume, and a little lime. There is no problem with this soakout. It does a nice job and the problems that we have had with it is in disposing of the sludge. If it is allowed to dry, it seems to get quite an oxidizer content. We have had two or

three explosions. We might as well use our term - we call them "pressure bursts". We don't like the term "detonation" either. The few incidents we have had have been pretty "rough". We have found that as long as the sludge itself is real wet or that the solvent itself is saturated, we have no difficulty with it. In fact, we have difficulty in keeping it burning, but when it dries out, it becomes a problem. I would like to recommend soakout for these engines for everything, if we have good solvents for them. We are getting some now that we have no solvent for, like the polyurethanes, and we have an additional problem in those particular ones because they start to cure when you start to mix them. They cure at ambient temperatures so if one starts setting up on you, you have a problem in digging it out of a mixer or casting can or something of that type in a big hurry. As I said, we have no solvent for it although we have soaked out some pieces of equipment by pouring the solvent I just referred to into the can and letting it leech out to surface and scraping off a quarter-of-an-inch of this at a time. That sounds a little unsafe, but I don't actually know how you are going to save a mixer or something of that type if you get it in there. We certainly are not going out and set afire a mixer with 1500 or 2000 pounds of stuff. We are still working for some kind of a solvent for this particular batch. Now, I'd like to discuss "cutouts" briefly. We have tried cutouts of several different forms. We have cut it out on lathes, and that didn't work very well. The problem in cutting out is in disposing of the chips and fines as they are being cut out because if you get a fire in one of these cases with the immense surfaces that you have exposed in chips and fines, you have a "pressure burst", and one that might even knock the walls down. However, cutting out may be the answer to some of the polyurethanes. If you are not going to try to salvage the propellant, there is no reason why you could not cut out in a stream of water. Wash the material out as you cut it out. I think that is one of the things we are going to do with some of the rejects we have recently made; cut them out under water or with water on them. I might mention here that I hold no brief for reusing scrap. We are very fortunate in the fact that we never make the same mix twice in a row. We do make many different types of propellant right in the same mixers so we are forced to clean our mixers out practically after each mix. We clean them completely with sawdust and detergent, so we have not had any problem with heels and things of that type. We burn them. I think they provide an excellent means of getting extraneous material into your mix. I have even seen heels dumped out on paper on the floor, and I don't know of a better way to pick up something than in in that method or even in putting it in containers. We take so much trouble to screen items, screen materials, pass magnets over it and go to all kinds of extremes to keep stuff out and then we throw a heel in there that we don't know what is in it - and you certainly can't screen it. That covers the items I wanted to bring up - does anyone have any questions?

Mr. Bishoff: I'm very interested in the safety precautions you take when you have to clean out the mixer, when it "sets up" in the mixer.

Mr. Stuckey: Fortunately, we have never had it happen in one of the real big mixers. It is a one-man operation. You pour the solvent in and let it set for two or three hours, and use plastic spatulas to remove the material off the surface. The only real precaution we take is making sure that the operator stands between the mixer and the door. We had an ignition of that type in an engine we were cleaning out that way. It is not like an ignition with an igniter. You don't light the entire surface of this thing at one time, and unless the man stops to pick up his tools or do something of that type, I see no reason why a man can't get out with an operation of that type. For small mixers, gallon, five-gallon, etc., I would suggest actually burning them out with water running through the jacket while you are doing it. We have done some lab mixers that way. I figure that we will eventually freeze up a fast-curing propellant in a big mixer and for a job like that, it would take you at least a week to clean it out.

Mr. Bishoff: Could you have a man stand by with a fog nozzle?

Mr. Stuckey: Well, we've had fog nozzles out. In fact, I've had these people from Ansul, but everybody thinks that they have something that will put the stuff out. So far, I haven't been able to find one that can put one of these propellants out when it is a 40 or 50 pound job. Use of the fog nozzle is to put the spray on the man in case the mixture lights.

Mr. Bishoff: I was thinking of keeping the man from burning up - like using the fog nozzles to keep the spray on the man.

Mr. Stuckey: Well, I actually think, in this particular case, we would be taking a chance with two men instead of one. I would rather take every precaution I can to get the one man out and make sure that the one man I put in there knew what he was doing.

Mr. Bishoff: Does he have to wear respiratory equipment?

Mr. Stuckey: It depends upon the particular propellant. We make one that is toxic, and in that particular case, he would.

Mr. Bishoff: You mention the use of a solvent. Wouldn't your solvent be toxic?

Mr. Stuckey: No, this solvent is not bad. We actually use a respiratory for it, but it is not bad.

Mr. W. B. Murphy, Office of the Deputy Chief of Staff, Personnel, Department of the Army: Do you have any information with respect to the generation of static due to the internal screen in the ventilation system?

Mr. Stuckey: I don't have anything on it. I'm not much of a static "bug" although there are certain operations in which I am afraid of static and that is where I have flammable atmospheres or dust conditions. On our operations with big grains where there is no dust and it takes maybe 650-700 degrees to autoignition, I don't worry about static. We have very little ventilation equipment of the type that I think you are referring to, and I have very little information on it.

Mr. Murphy: I was thinking of aluminum in particular, where you have very fine particles.

Mr. Stuckey: No - I don't think I have anything on it. I made this statement previously that I am not very much afraid of aluminum. Without the moisture, I don't think it is any problem. With moisture, you have to have a fair amount of heat to make it work. I think the problem there is: keep it dry or keep the stuff that you have under water out in the open and opened up. All of the aluminum containing scrap that we put out in our cans that we take to the burning field are always left open. We put no covers on them.

Mr. Murphy: This information, Mr. Stuckey, that you have presented - is this covered in any manual that you people have which others might obtain for guidance?

Mr. Stuckey: I think that we'd be willing to send you the information. We have it in the form of SOPs and operational things of that type. This is getting off the subject, but there is another item I would like to mention and that is that we are also trying to cut the case off the propellant we are testing. We are going to use a lathe and try to cut the case right down to the liner without affecting the propellant. The only reason I brought that up is, as a coolant during this process, we are going to use CO_2.

Mr. D. L. Saine, Olin Mathieson Company: You mentioned that you used a solvent for, I believe you said, the polysulfide composite propellants. You also mentioned that you did not have a solvent for the polyurethane propellants. Do you have one for the PBAA propellants?

Mr. Stuckey: The same one. We use methylene chloride and xylene mercaptan. The xylene mercaptan, incidentally, comes in at control of the base - it is already in the solution. We do it very simply: nine gallons of methylene chloride and one gallon of xylene mercaptan.

Mr. Saine: One other comment - you mentioned something about your dust removal during cutback. I think this corporation might solve it by the experience in the double base cutback during milling operations. I believe that there is quite a successful chip removal and dust removal system.

Mr. Stuckey: I like these slicer blades that cut your material in one nice big piece, but the big problem we have in cutback, of course, is getting fines down in the grain. Some of our divisions use a grain plug for that. You put a plug down into the grain to keep the fines from getting down in there. We are working merely on the theory that if the thrust is taken care of in the operation, and you have your engine fixed, if it does burn accidentally and is a normal burning, you won't have too much of a problem. You'll hate to report it, but still it shouldn't be too terrific an incident of any kind. If the fines get down in there, then you probably will have a terrific burst.

Mr. Shaefer: In the soaking and scraping out operation for a mixer charge, does the operator use asbestos clothing, face shield, etc.?

Mr. Stuckey: No. We use plain treated uniforms that are flame retardant. (We use DuPont products.)

Mr. Shaefer: What about face shield. Is that used?

Mr. Stuckey: No. We don't use a face shield. I'm working strictly on the theory that an ignition of this type would probably be caused by impacting - like between the scraper and mixer, something of that type - and that it would be an ignition that the man could get away from. For example, we had this happen: just because we thought that eventually we might have a mixer freeze up this way, we cleaned out a couple of pretty big engines in this way and also a casting can. Where the surface is this big, we also used an auger and drilled little holes which helped this process tremendously except that we couldn't drill them up close to the sides of the casting can nor near the bottom. The webbing would break out easily. In the case of the engine, we filled it full of material and every four hours we would dump this out and scrape this soft material off. This was a rather large engine and we developed a spatula, a big spatula, to get at the stuff down at the bottom. The operator cleaning the surface was a little too enthusiastic in his effort to scrape some of this near the bottom and the spatula slipped and hit the bottom of the case. It popped like a Twenty-Two - just about like an impact test that we make in our plant - and started to burn. He didn't lose any time leaving. There were also three other men in there on another operation. We stopped that. There were also two or three other engines lying there which also ignited and blew. When the first incident occurred, the other operators saw the man who was working on the thing leave so they decided it was time for them to leave too. There was no problem, and I don't think any of them were in any real difficulty. In fact, one of them was actually carrying one of the engines of the same type that blew and he ran about 100 yards with it before he stopped, set it down, and took off again.

Mr. Jezek: Max, I have a question. No doubt when you burned this scrap which is contaminated with solvent, you ignited your train with squib. In the event that you don't use scrap, the old question has

come up again as to whether we should light into the direction from which the wind is blowing and so on. How do you do it out at Thiokol, and what was your experience in Kansas?

Mr. Stuckey: We light into the wind at both places. We use electric squibs at Kansas. We don't like them down here. We use safety fuse. We end the safety fuse either in a hand full of dry scrap propellant or end the fuse up in a little hand full of uncured propellant; then into a little train of excelsior or something of that type, and then into the propellant. We light into the wind. It's burning into the wind, but we have always been afraid of that because we have quite a bit of wind that is very changeable down here. I wouldn't want some of the gusts I've seen blowing this flame out ahead.

Mr. Jezek: In other words the wind is blowing towards you?

Mr. Stuckey: You get plenty of distance for your operator but we never stay out in the burning field. It is a remote control operation. Only one man stays, incidentally, to light the safety fuse. It is about a ten-minute fuse. Everybody else leaves before the fuse is lit. We observe it from our observation station, which is about six hundred feet, so we can see if some material does get out of the fields to start grass fires.

Capt. Jenkins: I have one note of possible interest there. In the military establishment there are several methods which could cause ignition of the propellant scrap to be disposed of at the burning ground. One method, of course, is to make ignition with the wind blowing toward the operator's face, and another service uses it just the other way around, so the Armed Services Explosives Safety Board, in trying to get some unity on this, came up with "blowing down the middle." That is not just a way to arbitrate it; there is a lot of good justification for it. In fact, that is under some serious study right now by the various services.

Mr. Stuckey: I might add one thing here concerning burning hazardous materials. In the ordnance plants where we have production items of some type, we didn't run into anywhere near the problem that we had here when there are constantly new items that must be burned on the field, such as new oxidizers and new propellants. Some of them haven't even reached the stage yet where you know whether the smoke is toxic or anything else. You know very little about some of them. When they first show up in the samples, you've got to burn out at the burning field with your other material. We do have a practice, and I think it's a good practice, that if any new material must be burned, burn it seperetely until it is proven. That is a hard thing to control, but it is worthwhile if you can establish it. Otherwise, we have some of the new ones that we are working with now that you can hardly burn with a blow torch. Once you set them on fire, about nine times out of ten, they blow rather than burn although they are not supposed to. We found that some of them, for instance, that

had the same nitrate, have to be put with something else actually, to burn. We mix them with sawdust like we do out AP's. I think that we may be getting into trouble by blowing some of this burning propellant out adjacent areas, and we don't have much area there. I think that these should be burned separately until you have enough faith in them to burn them with the other material.

Capt. Jenkins: Thank you very much, Mr. Stuckey. We will have just one short one. We are running behind. I want to get Mr. Buxton in on this, too.

Mr. Saine: I believe you commented a moment ago to the effect that you didn't believe that you could extinguish a sixteen-inch composite type propellant grain with a deluge system. Was that correct?

Mr. Stuckey: Yes. I don't know of any of them that we have put out yet: I don't say that you couldn't get enough water. I do know that with the water supply that we have available, we can't put it out. Our construction set-up is simply not to give the stuff anything else to burn. If you are going to have a thirty-second or a forty-second fire in a pit or in a building and you give it nothing to burn, long before you can get your fire apparatus going or anything else, the thing is all over and you can go in and do something about it. Of course, that isn't the type of fire that we had, but that's the type we are going to have from now on, I think.

Capt. Jenkins: Mr. Schaefer, I'd like to get Mr. Buxton to add any comments that he and his people can make on this, and then, perchance, he might answer the question you're interested in.

Mr. Buxton: I think that we are already "on borrowed time" so I'm going to make this brief. I think Max covered things very well although I would like to go into the subject of the collection of scrap propellant. We found that some very outrageous safety practices were being followed by the maintenance group that picked up this scrap propellant that we wanted to get rid of. This, of course, in a research and development operation like we are heavily into, can involve a bit of tonnage. I don't mean to use that word loosely, but actually, we burn upwards of two or three thousand pounds of scrap propellant a day. I hope that doesn't shock anyone. Actually, we are running tremendous numbers of environmental tests and physical property tests on this material. We found out its elongation, its elasticity, etc. You've got to get rid of this stuff, and naturally we have quite a lot of it. I won't tell you what we found but I'll tell you what we have, at least now. We have a special truck that does nothing but this, and we have special men that do nothing but this—collecting scrap propellant. I think that this is quite important; our truck is about as spark-proof as you can make it, and this, I think, is desirable. It is completely stainless steel lined, has a spark-proof

exhaust system, a non-sparking ignition, and so forth. Then the men themselves we made as spark-proof as possible. This is something that had been apparently overlooked. True, they were wearing conductive shoes and had some kind of protective coveralls, but there was quite a bit that had been overlooked itself. This is something that might seem to you "offhand," but it is still basic and fundamental. You don't even need to think about it again, but you might look into this. Who is picking up your scrap propellant? They might be a real hazard. Now one other thing that we looked into is this. They were using polyethylene bags to put this scrap propellant into, whether it was uncured, cured, or samples of burned metal tests, etc. Here we discovered that it was possible to get a static spark from your polyethylene bags. Maybe some people have had more experience with this than we have, but it scared us quite a bit when we found the degree of static sparks we could get from a polyethylene bag. We are now getting spark-proof or at least conductive polyethylene bags. I didn't know whether you folks knew that this was available, but there are two companies in the country that make spark-proof polyethylene bags, and I understand that they would like to have comments of this sort, or some sort of a write-up of this program and I'll include that in my comments. If you folks are interested in where you can obtain spark-proof polyethylene bags, I'll give you the information later. One other thing that I wanted to mention, and this apparently has not been important enough for you folks to even feel should be on the program. It is this matter of "struck-spark generation." We talk a lot about static, but I don't know whether you realize that if you permit someone to come into your plant with hobnails in his shoes, leather heels, or cleats on concrete he can strike a very hot spark--much hotter than you'll get with most of your static problems. We ran a few tests on this to see what we could get. It's possible, actually, to estimate the content of the struck spark. This, too, I will be glad to send to the Board if you'd like to know how we arrived at this. I had a few notes on this that we had worked up. We naturally had to make some assumptions on this. On the weight and size of the particle, for instance, we used about a hundredth of a gram, which is a pretty heavy particle, and yet, conceivably, if a person fell or gave a real hard kick with his shoe, it would kick off this much. On the basis of the specific heat of steel (the melting point of steel is approximately around 1500 degrees centigrade), we came up with a theoretical figure of approximately nine-joule spark. From the talk we had yesterday, Mr. Owings, you recall that it takes three to ten of nine power, something like this in joules, to set off at least vapors, and we feel that we probably could set off even uncured solid propellant with a spark of this intensity. So, this gets back to the man that is collecting scrap propellant. First, he should have conductive shoes and be sure that he doesn't have any metal entrapped in them. One other thing, while I'm speaking of this struck-spark business, and I don't mean to question the procedure following here at NPP, but we like as a static eliminator - a conductive strap that actually covers the sole and heel of the shoe. There are several varieties of this. The kind we use is the International Shoe

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Company variety that slips in the side of your shoe as well as over the back, and if you'll recall, it comes from the toe of your shoe clear back over the back to the heel, so if a man had cleats in his shoes, he is still walking on the conductive rubber. Now, this takes care of that problem. We also have used these yellow patches that I know Thiokol used, and Don is actually the fellow who put me in touch with the company in Philadelphia which sells them. The name of the company slips my mind - it is on Cockman Street in Philadelphia. Now, this has two advantages; if you are using your conductors that you use here and you put these yellow patches on their heels, then you have accomplished what I am interested in - the struck spark. It has one other value, and that is in trapping any material in your heels, particularly in a rubber heel with these little holes where the nails go through. At least, in our plant, you could, in certain places, get uncured propellant entrapped in these holes and later you might twist your heel and get something out of place and explode this and possibly burn or hurt somebody pretty seriously. You all know what I am talking about, I suppose, with these yellow heel patches. They are nothing but - I guess it is polyethylene or something - that has some "stickum" on one side like scotch tape. You can just put them on your heels and pull them off very easily. The only other thing that I would like to mention that we had a little trouble on was the matter of disposal of water-washed dust or well-ground-off propellant. Our machine operations that we do wet - we use almost 100% wet machining of our free-standing grains. What becomes of this? Where does it go? Assuming you are working with a lathe or something, and machining this stuff off it - the fines go down and it is washed down - it gets in a flume and it goes out of the building, etc. Watch very carefully what becomes of the real fine fines on this. If you are leaching it into the ground or something like this, it can pose a real hazard because some day a bulldozer might come along in this area. This happened in our plant several years ago and practically blew the track off a bulldozer which ran over it and ignited it. The ground got thoroughly impregnated with good old Aerojet propellant, and it didn't like being walked on by a bulldozer and it actually exploded under the track. That is about the only thing that I had to add to Max's comments which I thought covered the subject very completely.

Mr. Henry F. Harris, ASESB: Just about ten minutes ago, a phone call from the Board was received, and they said that Mr. C. W. Byers would be in attendance on the 10th and 11th of June in place of Mr. Robillard. He will speak on the subject that Mr. Robillard

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was to present. I want to make sure that Mr. Byers has an opportunity to speak on this subject, if he is present. I don't know his whereabouts at the moment, so we will continue with the agenda.

Captain Jenkins: If we have time, when he arrives, we will hear from him. Captain Clark, USAF, will take up the interesting subject of methods of determining explosives hazards of solid propellants.

Captain H. T. Clark, USAF, WADC: I am at quite a big loss here. I found out since preparing this speech that the Board has had another meeting on methods of testing which has sort of "cut the water out from under me", but I'll go ahead, and probably add a prologue. I heard how some of these experts have been selected to show up. I think I have the best one of all. I made the mistake of going on a three-week vacation and the last day of my vacation, they called me up and asked how long my speech was. Mr. Adkins was real interested in knowing how long I was going to talk. This is the way I found out that I was going to be here. We, of course, welcome this opportunity to discuss methods of determining explosives hazards of solid propellants for rocket motors. This will be mainly oriented to the end item rather than the propellant itself. This discussion will include the following items:

1. A summary of the explosive classification tests required by Mil-D-26389(USAF).

2. A summary of the major revisions to this specification which will be required to meet the Armed Services Explosives Safety Board's proposed minimum criteria for determining hazard classification and the financial impact of these changes.

3. Possible means of reducing the number of motors required where a major expenditure of funds is involved.

Mil-D-26389(USAF) covers the data presentation requirements for determining safe handling, storage, and shipping procedures for rocket motors and their components.

Previous to November 1958, the required tests were specified in Mil-E-25532(USAF). There were 4 main faults with the old specification.

1. Test requirements were not clearly defined.

2. Test methods were not specified and therefore differed with each testing agency.

3. The method and requirements for presenting test data was not specified.

4. The tests were expensive and potentially dangerous in the case of large motors.

All but the latter deficiency was resolved in the new specification by clearly specifying test requirements, the general test method and type of equipment where critical, test data to be taken, and the method of presenting results. These changes assured that proper data was obtained and also permits a more valid comparison of data from various agencies.

The most difficult fault to correct was that of expense and danger involved in testing large motors. The decision was to make the following changes.

a. Allow the substitution of sub-scale motors for full scale motors. Air Force approval is required for this substitution as in some instances it may not be desirable. The sub-scale motor is defined as a motor that length equals the full scale motor's diameter. Great reductions of propellant weight can be accomplished in some instances.

Tests are being conducted under the Bomarc development program which should confirm the validity of the implied assumption that negligible changes in test results are introduced.

b. Expense of the test was largely reduced by decreasing the number of motors required from 30 units to 6 units.

A brief description of the content of the new specification is in order. The specification includes tests for impact sensitivity, propagation of a detonation, effect of fire and propellant autoignition.

The impact sensitivity tests consist of the 40 foot drop test for the rocket motor, igniter, and standard propellant grains. The standard grains are 5" x 5", 5" x 10", and 10" x 30" (diameter x length). Motors and igniters are also subjected to a 30 or 50 caliber bullet test. Propellant and igniter composition impact sensitivity tests are conducted using the Bureau of Explosives impact apparatus. The oxidizer content of the propellant being tested is varied over a wide range for this test. Tests are conducted at -75°F, 70°F, and 170°F.

Propagation of detonation tests are conducted on the rocket motor igniter and four each of standard grain sizes laid end to end. Tests are conducted using a number eight (#8) blasting cap. The motor and standard

grain tests are followed by one using a #8 cap with a booster charge of 100 grams of C-4 composition if a detonation is not observed using the cap alone. The propellant detonation test consists of attempting to detonate loosely packed propellant of a given particle size range in a 10 inch diameter, four-foot long pipe. 100 grams of C-4 composition and a #8 cap are used if a detonation is not obtained with a cap alone.

Effect of fire tests are conducted on a rocket motor packaged for shipment and on wooden crates, each containing four standard grains of the same size. An effect of fire test is also conducted on raw propellant as received from the mixer. The raw propellant is contained in a pressure vessel designed to rupture at 5000 psi.

One hour and eight hour auto-ignition temperatures are determined using a Wood's Metal bath. Ten gram samples are used in this test.

Several major changes of the new specification will be required when the proposed minimum test criteria are adopted by the armed services. These changes would consist of eliminating the option of using sub-scale motors for tests, adding motor and igniter confinement tests, substitution of Engineer's Special blasting caps for #8 caps, substituting 30 grams of tetryl for 100 grams of C-4 composition, and increasing the number of test motors and igniters.

The increase in number of motors required and elimination of scale motors will greatly increase costs for motors exceeding a million pound-seconds of impulse. The increased cost in motors on one Air Force program would involve $250,000. On the basis of economics alone, it is considered advisable for the armed services to seek new methods of testing.

Perhaps the most intriguing approach that can be imagined is one of using the propellant's critical diameter as a tool for reducing or eliminating the need for full scale motor testing. Assume that the propellant's critical diameter has been determined. Also, assume that an equivalent diameter can be determined for the motor's grain configuration. Define equivalent diameter as being the diameter of a right circular cylinder which is equivalent to the motor grain with respect to propagating a detonation. Wall effects and the effects of length to diameter ratio are being ignored for sake of simplicity.

Intuitively, the equivalent diameter would appear to be less than the motor diameter and probably equal to or greater than the web thickness on a case bonded internal burning grain. For the moment assume that the equivalent diameter is equal to the largest circle which can be inscribed on the longitudinal cross section of the grain.

Knowing the propellant's critical diameter and the motor equivalent diameter, several interesting possibilities are evident. If the equivalent diameter is less than the propellant critical diameter, it would appear logical to conclude that a detonation cannot be propagated in the motor.

Therefore, the motor detonation test could be eliminated.

Another interesting possibility is a method of eliminating tests simulating confinement, again assuming the motor equivalent diameter and propellant critical diameter are known. If a relationship can be found which expresses the degree of confinement in terms of pressure, mass, and heat losses, it may be possible to adjust the propellant's critical diameter downwards to correspond to these conditions and to make a comparison with the motor equivalent diameter.

However, in actuality, confinement tests with more than one motor become unrealistic when considering large motors. Storage and handling conditions will be such that close confinement in the sense of the proposed minimum criteria will not exist.

A program to verify the existence of these or equivalent relationships would be expensive. However, consider the cost of conducting an explosive classification test on a 50 million pound-seconds impulse motor. The cost of such a motor will be on the order of 1.0 million dollars. Assuming confinement tests are not required, the minimum test allowed by the proposed criteria is three detonation tests and one fire test for a total of 4.0 million dollars for hardware alone. The propellant weight for such a motor would be in the order of 100 tons. A high order detonation of such a mass of propellant imposes severe real estate problems. Even if only ignition occurs, positive methods of restraining all of the motor components will require use of elaborate test facilities.

In conclusion, it is hoped that current explosive classification methods used by Wright Air Development Center have been adequately covered and further, that the need for reductions, rather than increases, in motor testing, in the case of large motors, has been adequately conveyed.

Use of the concept of equivalent diameter for reducing testing has been presented for the purpose of stimulation. Although the reasoning that some such method can be found is considered sound, technical substantiation of its validity is not available. It is but one of several possible approaches to the problem. Are there any questions or comments at this point?

Captain Jenkins: The Board has been doing a considerable amount of work trying to get uniform hazard classification standards out. Before any questions are asked here, Mr. Herman will give some information on what we have done, the progress we have made and the status of it at the present time, which might answer some of the doubts you may have. Mr. Herman?

Mr. R. C. Herman, ASESB: Gentlemen, I am afraid that I am responsible for causing Captain Clark's dilemma up here this morning. This problem of hazard classification has caused considerable difficulty ever since the advent of this rocket and missile era. The Board has attempted to develop

a standard test criteria to cover these items. We worked for some time on this and about a year ago, we came up with a minimum test criteria. Our main difficulty was that we realized the cost of these larger units but we could find no one who could give us any information at all as to how we could get around using a large scale unit. We contacted all the Services and various test agencies and everyone said yes they would like to do it, but they couldn't possibly use full scale, and couldn't give us any basis to work on scale models, so we came out with a minimum test criteria for various items and we put in a statement that, until information was developed, we would have to use full scale items in testing these large motors. Right away everyone said they couldn't do it; it would cost too much money. Just about the time that this was published, Dr. Amster was doing a good bit of his work. He hadn't started the tests; they were planned at this time. Since that time, Dr. Amster has met with us several times and given us very excellent guidance and we have changed the criteria which hasn't actually been published yet. The meeting was held on the 28th of May, but we finally came to an agreement of using scale model items and the criteria for this was based on what Dr. Amster gave us--this equivalent diameter, with a length of about 3 times the diameter. Everyone seemed to feel that for motors up to and including 17 inches diameter, that you have a sufficient number of these, perhaps rejects, that could be used full size and this wouldn't cause any great difficulty. At present the criteria calls for utilization of full size motor up to 17 inches. Greater than this you will use this scale model which is a grain diameter equal to the equivalent diameter and a length of $3\frac{1}{2}$ times this. The other thing that enters into this would be a type of confinement or case which would be equivalent to your case thickness of the full scale item. We ran into further difficulty, insofar as we were trying to lump three problems into one, and I think this is one thing that did cause a lot of the original difficulty. We have three different types of classifications which we are trying to solve. One is transportation to meet the requirements of the ICC. The second is a storage configuration in your depots and of course, the third is your siting or user type of configuration. Generally speaking, in the first two, you are going to have these motors as separate items; they won't be complete units but will be broken down. Perhaps your warheads would be stored separately in most cases. So we decided to tackle the problem in this manner. You would first test the items as separate items, your motor separate from your warhead, to see if you got an explosion of your motor based upon a slightly overpriming (by "over" I mean that the ICC requires a priming by a #8 blasting cap and that you shall not have a detonation or an explosion more than 50% of the time). We have taken the attitude that we want to be just a little better than this in establishing our classifications, so we have upped this to an engineer special blasting cap with a 30 gram tetryl pellet, and you shall not have an explosion at all. If you have an explosion, this would automatically go up to class 9 and 10. If, on the small scale, you do get an explosion, then you need not test any further because, I think Dr. Amster brought this out, if you get an explosion in a small item you can be sure you're going to get it in the large item. However, the converse is not true, if you get a burning from the small item with this type of priming, we feel that when you get over

into the user type where you will have your warhead which would of course give you a greater boost, etc. and you want to be able to have some figures to use for siting, then you must test with your warhead. However, on these particular user type of tests there is little minimum criteria given. We feel that these would have so many variables it would be impossible to come up with one standard criteria and that it will be necessary to develop criteria for these tests as you need them. We hope that, in the very near future, this minimum test criteria will be made available to you; we also hope and feel that this isn't the last word by any manner or means. It's something we're going to have to constantly review and revise as new experience comes in. We feel this will help everyone insofar as the three Services will agree on one test and the Service that has the basic original design requirement can run the test that the other two Services will buy without each Service having to run a different type of test. This is our prime objective. I hope this will answer some of the questions and if there are any further questions I will attempt to answer them for you.

Dr. Ball: I could probably talk all day on this subject, but I am not going to do it. In the first place, I am in hearty sympathy with the viewpoint that the three Services should get an integrated program on this matter of hazard classification and that the ASESB ought to be the clearinghouse. Frankly, as of less than, maybe a week ago, I know that wasn't the case. There are still missile contractors around here who read in their contracts that they have the determination of the hazard classification of the birds they're working on as a part of their chore. Is there anything that can be done to speed this integration and at least get these folks that have to make recommendations on them coordinated with you people?

Mr. Herman: Dr. Ball, I cannot answer this specifically; however, I believe that the intent of this document, when it is put out by the three Services, will answer this. That this will give a firm minimum test criteria which would have to be met. This would have to be up to the individual Service as to whether they would allow the contractor to run the test and submit the result to them or whether the Services would run the test at one of their own facilities. For the last several years, BuOrd has been conducting tests at NPG Dahlgren on all three Service items that are presently in the pipeline, trying to get it up-to-date. But perhaps Mr. Endsley or someone else might be able to answer your question as to whether this will be forwarded on to the contractors to utilize.

Mr. Endsley: Captain Clark, check me if I'm wrong, but we intend to integrate these minimum criteria into the military specifications which will become a part of the contract which was awarded to test these items. We have a little problem in the user type situation where a contractor is only responsible for producing an item and he is only responsible for assessing the hazard for that item as an end product. When we get it into a user environment, we have a little different problem altogether. This is where you get the increased donor. Maybe Captain Clark has something to add to this.

Capt. Clark: I might say how we have done on Bomarc. There we have contracted out the test to a document which we had Boeing write to our requirements because the Mil Spec wasn't out yet. However, their responsibility ceases when they have contracted for the testing; the analysis of the data will be up to WADC for the R&D phase and OOAMA for the production phase.

Dr. Ball: Let me proceed to my next comment on this. I don't really understand why you folks worry about the cost of making a full scale test. The cost of a full scale hazard classification test, even at the kind of figures you're talking about, is very minor compared to the cost of one aborted flight. I myself am suspicious of scale model tests because I think we don't know enough about the scaling laws. True, through work like Amster has done, we are beginning to learn something about it but I just don't believe we know the scaling laws. With regard to your statement that you can shoot something of a small size and you can be sure that it will also shoot in a large size, I can quote you an exception to that on bullet impact work which was done under my immediate supervision a few years back. We found that, except in the case of primary explosives, if you're going to initiate a disturbance in a bullet impact, that disturbance is going to be initiated when the bullet leaves the sample and not when it enters. The mechanism is that you pinch the explosive between the projectile and the outgoing wall. If you can get a successful shot on bullet impact in your sample, where your bullet goes out the second wall, you can scale that thing up to where the bullet stops inside and you'll never start it.

Mr. Herman: Of course that type of test would be considered as a user type under this criteria. We are utilizing overprimed ICC requirements. This is where you would use tetryl and blasting caps. I agree with you that all this is very new. As I said, a year ago before Dr. Amster ran these tests, we had no information but we are attempting to come up with something that we feel is reasonable. I would like to say one other thing concerning hazard classification; we are not too interested really in the technical term, whether it's a detonation, an explosion, or a deflagration. The primary thing we're interested in is establishing hazard classification as the end result. It might be a deflagration, this is true in the true sense of the word, but still if it can blow out the wall or knock down the house or wreck the town, we want to know it. We want to know the ability of this item to do damage. We don't care whether it's called a Z or a W or a 2.

Dr. Ball: You are quite right on that. I'm sorry I don't have it with me, but I have had in my possession a picture of a static range that was taken apart by something that was definitely not a detonation, but it sure was taken apart.

Mr. Herman: As perhaps you recall, Dr. Amster made the statement that even though he could tell you technically whether this was a deflagration or a detonation through these various tests, there was very little he could do to tell you the TNT equivalency of this item. It may be greater than TNT. Even though it might be deflagration, it could be 95% of TNT and still do an awful lot of damage as far as property and people are concerned.

Dr. Ball: My last comment is that I'd like to commend your viewpoint--that what you have to test here is the package. If you're shipping, the thing exposed is the unit crated. The test should be run on the crated unit with the disturbing factor not closer than the outside of the container.

Mr. Herman: Another thing on which we have gone a little greater than ICC, we feel that the new methods of shipping are quite frequently in trucks. You have an entirely different hazard when you ship by truck than when you ship by rail. One of the tests we have included is the external fire test. We take the item placed just as it would be in a truck, up off the ground on a wooden crib, scrap lumber dumped around it, and then maybe 30 or 40 gallons of diesel fuel poured over it, to simulate an accident where you would have the stuff jumbled, where you would have the fuel tanks ruptured, to see what happens, how long will it burn, will they detonate, burn, or explode. Just what is the end result.

Dr. Ball: That's probably your most significant test of all because of the accidental exposures; fires are much more frequent than any of the other things. I might suggest one further extension of this package concept; if you do find that you can propagate explosions from one unit to another if they are in immediate contact, and you fail to propagate if they are separated by one diameter or something like that, then you should consider that your magazine is your package and if the magazine is properly stowed it should be class 2, and where improperly stowed, should be class 9.

Capt. Jenkins: This gives you a little insight on a problem we were faced with a year or so ago. Originally we felt the full scale testing was in order; then there were certain objections to the money, and now we've learned something in the past year. I hope that in a few months we'll have some kind of guidance out to the Services to guide civilian industry. I see Dr. Amster is here. You can start asking him questions and Doctor, you can supplement what Mr. Herman has said.

Dr. Amster: First of all, I'm inclined to think the problem is going to solve itself pretty soon. It has arisen, I think, because the propellants which we have been using and which are in bulk production as I understand it now, have large critical diameters. The materials which are being examined experimentally have much smaller critical diameters and more closely approximate explosives so I think pretty soon it will be possible to run these small scale tests and apply the explosive technology which we cannot use now. I don't have much else to add except a few people have asked me what is a "detonation." A thumbnail answer, I think is worthwhile bearing in mind. First of all I made a comment before to someone that I'm a little afraid of where the regulations we're worried about specify detonation. I think maybe this word should be changed and we should say explosion instead. Because as far as safety is concerned, this is really what we're worried about in general. Detonation has a very, very precise meaning as I'm sure most of you know, and at the risk of repeating what is pretty well known,

I'll say, in my mind, what I mean by a "detonation". If we imagine a stick of explosives or a stick of anything with a process beginning at one end and traversing down the length of this stick, if this process occurs at a linear rate which is supersonic with respect to the unreacted material, this is by definition a "detonation". If it is subsonic, it is not a detonation. There is another criterion which can be used and mathematically, they are equivalent. You people watch your cigarettes burning; it burns this way and the particles come off in that direction, and the smoke goes away. If you ever notice the particles moving in the same direction as the flame, get out of the way, it is detonating. So, when your phenomenon philosophy - I hesitate to use the word "shock" - well, let's use it. When the shock velocity and the particle velocity are in the same direction, you have a detonation. When the particles are moving away from the flame front, you have a deflagration. Both phenomena can be classified as an explosion, which is a general term, and that is why I said yesterday, when I was using the word "detonation", I meant detonation - I did not mean explosion. One other thing - to emphasize what perhaps I didn't get across as clearly as I meant to yesterday. Certainly, as has just been stated, we do not have any scaling laws which permit us to say what the damage is going to be when a large missile is subjected to a shock. I don't know that we ever will, frankly. Certainly in the tests I discussed yesterday, these 20" diameter things which we call "Beauregard" tests, and have been reported as such in literature, in these tests we very definitely learned, I think, that the amount of damage is a function of a great many things, including the geometry of the sample. This is not just diameter we are talking about, it is where the charge is with reference to the shock. For example, the charges which we did discuss yesterday, if you remember, we had a booster which was 20" long and a cylinder of explosives which was 80" long, and we got certain TNT equivalents. Now, whatever TNT equivalent you want to accept, I assure you that if we had doubled the length of the charge, you would have gotten a much smaller TNT equivalent. If you would decrease the length of the acceptor charge, you would have gotten a much larger TNT equivalent because what we have is a process where you have a fire, or deflagration, or an unstable shock, if you will, propagating from one end - the end nearest the booster, and gradually decaying. Now, obviously the contribution to the damage that is done in this process is going to depend very much on the geometry, and until we have some laws about this, we are not going to know what to do. That is why I say that if we get into the far more sensitive propellants, this is not going to be a problem because they are going to propagate whether you start it from one end, or in the middle, or perhaps a few feet away. I don't know if the latter is going to hold, but the more closely we approximate explosives with our propellants, of course, the more hazardous the situation becomes. On the other hand, the more we know -- because we know a lot about explosives and we don't about propellants. Finally, I think it's worthwhile noting that there was a paper given at the AIP meeting in Quebec a few weeks ago by John Heiman absentia from Rohm & Haas, Redstone, and he proposed something which I think is well worth remembering - that arbitrary classification of propellants, Class 1 or Class 9 or whatever else it may be, is just not going to work because the classification varies, whether you're processing it or storing it or using it. I just don't think we

can apply arbitrary classifications and say categorically from cradle to grave that this material has such and such a classification. It's just not going to work. That's it.

Capt. Jenkins: We have time for a couple of questions. Mr. Murphy?

Mr. Murphy: I believe yesterday you referred to the critical sphere and Captain Clark this morning referred to a critical right cylinder in his investigations. Are you both talking about the same thing?

Dr. Amster: We're talking about two different phenomena I think. The critical sphere I was talking about was the self-heating sphere. The data can also be reported in terms of slabs and cylinders. They don't differ very much, I think by about a factor of 2 if you're talking about a self-heating experiment. Critical diameter for explosion is something else, we don't know yet what the relation is between the critical size for self-heating and the critical size for detonation. This is one of the things we hope to find out.

Mr. Murphy: I wondered about the geometrical figure. Doesn't this make a difference?

Dr. Amster: Yes, it does. But as far as the self heating is concerned, this is what I was talking about with the sphere. The relationship between the sphere, you see the reason we can talk about spheres is because you can make it a one-dimensional problem, mathematically. The sphere you can work from the center out and this is the radius, and wherever you go the only parameter which is effective is the radius. If you want to turn it into a cylinder, it has to be a cylinder of infinite length so then again, the only variable parameter is the radius but there are relations which can be established and they differ by a factor of 1½ or 2 for the radius of this infinitely long cylinder and the radius of the sphere. I don't know what the numbers were this morning, I was a little late, some of you know, so I shouldn't comment on it here.

Mr. Murphy: I understand the distinction that you just pointed out. Captain Clark's interest, of course, is in the particular kind of model which would be suitable for determining whether a full-size grain would explode or detonate.

Dr. Amster: Spontaneously, from heating.

Mr. Murphy: Not from heating. From shock.

Dr. Amster: This is another problem. Then we have to put aside the spheres and cylinders and slabs I've just been talking about and as yet we don't have any model....where the particular parameters are. It's cheaper at the moment to run the problem on a bomb-proof than on an IBM 704 because at least we do come out with an answer.

Mr. W. Weintraub, Space Technology Laboratories; ARDC: We had a go-round with Dr. Ball concerning this explosives classification. One thing that interested me was what Clark said about not attempting to test a full scale. We are in agreement with Ball and several other associate Minuteman contractors that it is necessary because we do not know the scaling laws. However, I would like to direct one question to Captain Clark and that is, how do you arrive at this pseudo or so-called pseudo critical diameter?

Capt. Clark: Well, I think about the best way, I proposed that perhaps this 4,000,000 dollars we're going to be spending someday in the future to buy this hardware, if you'll notice, I hypothesize and I think what we need to do is to get in and do some basic research. It probably won't help you at all, it's too late, but we need to study the problem a little more theoretically and come up with some experiments that will either verify our assumptions or prove them wrong. It is along the order of the work that is being done by Dr. Amster.

Mr. Weintraub: Aerojet is also conducting similar experiments and as far as we can tell, he would also like to conduct the full-scale test because of the fact that we're ignorant of the scaling laws.

Capt. Clark: It is true, you're going to have to come up with an experiment which will either prove your assumptions are either right or wrong.

Mr. Weintraub: I agree with you, but for the Minuteman program, it looks like we're stuck.

Capt. Clark: Yes, it does. I'm not trying to sell you anything, I just don't want to have to test this thing, a hundred ton grain, this is what I'm trying to head off.

Mr. Waite: Dr. Amster, have you tried to extrapolate the relationship of the card gap and critical diameter of your experiments to propellants?

Dr. Amster: We're beginning to, let's put it that way. There are some old data on critical diameter of explosives in an OSR report dating from the war. We have, of course everyone thinks his own experiment is a little better, we are beginning to get data on critical diameters for explosives in which we have good information other than critical diameter. As things stand now, we have three critical diameters for each of three explosives. Unfortunately there is an inversion between the critical diameters and the card gap. But I say three points don't make a theory. We are going to need some more data. Incidentally, there's one thing I think is good to remember. In these gap tests, if we want to go ahead, we have to remember what we're testing for. If we're testing for detonability, you've got to design the test with a monstrous booster and a monstrous acceptor and the joke is they're lowering the budget now by blowing the missiles up at the plant rather than down at Cape Canaveral. Maybe this is what we want to do, put a few of these million dollar missiles into a gap test to find out, rather than blowing them up at Canaveral, but what kind of a blast is it

that we have to postulate we're protecting these things from. We had 1500 or 1700 pounds of propellant and in order to test this profitably, we had to put in 780 pounds of Comp. B, now I ask you where is any missile going to be subjected to the blast of 780 pounds of Comp. B within zero inches. If this is the kind of a thing that we're worried about, let's not get ridiculous about it.

Mr. Haite: If you can make such an extrapolation, I assume that you're going to then come up with a critical diameter and try that diameter?

Dr. Amster: This is what we hope to do, yes. Not only are we going to try and get critical diameters and see if there is a relationship, but also thermodynamic properties, kinetic properties, anything conceivable, strictly a "seat-of-the-pants" program.

Mr. Haite: One thing that I mentioned yesterday. I'd like to point out that even though you have a limited number of propellant formulations and you're looking for any formulation that someone will give you, I would like to point out that your critical diameter, your card gap tests and everything else, that these numbers will vary undoubtedly with the percent of loading.

Dr. Amster: You mean the percent of oxidizers, yes.

Mr. Haite: And also that the density of the binder will have definitely some effect here.

Dr. Amster: Undoubtedly.

Mr. Haite: The high density binder, you will not load it as heavily to get initiation.

Dr. Amster: No question about it.

Mr. Haite: Thank you.

Dr. Amster: But if somebody will send me the samples, we'll give them the numbers.

Mr. Weintraub: We realize the fact that designing an optimum booster would probably take up to 2 or 3,000 pounds of Comp. B on a large size engine. However, it has been suggested that perhaps a solution to this is to determine the threshhold at which one of the engines will go. In other words, design the booster pellet so that you just hit the threshhold. What do you think of this?

Dr. Amster: I think it's a fine idea. Incidentally to correct your 3,000 figure, Al Gaylord and I were together trying to design the test for something called the Polar Bear. It turned out we had to pile two of the motors, one on top of each other, in order to get a suitable diameter ratio. This was a conservative estimate, it wasn't the booster that would really do the job, it was the one that was most reasonably consistent with expense and handling, etc. I think it was about $3\frac{1}{2}$ or $4\frac{1}{2}$ tons whereas the one that

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would have done the best job would have been 7 tons of Comp. B. This was one of the reasons the thing was cancelled. I might point out, by the way, that there is one test that is worthwhile considering if you're worried about damage. As long as we're working with internal burning grains, it's something that can be done and it possibly can be scaled. The worst possible situation can be reproduced about as follows: If you take a grain and load the core with high explosive and then set off this explosive in some reasonable fashion, I think the damage that is going to be done by internally loading at these very high detonation pressures, internally loading this grain, presumably it will propagate in some fashion. Whether it detonates is immaterial and you're going to get the maximum contribution from the propellant that you can possibly get under any circumstances, and if you're looking for the worst test, this is one that can be done and I think it could probably be scaled. A little experience could tell us something about this.

Mr. Weintraub: I can understand getting into the internal portion of the grain but when you consider that we have propellant mass ratios of .92, etc., the confinement is almost nil.

Dr. Amster: I have not solved the problem up here I know. I think this is something we might be able to scale; we might be able to make some smaller grains with a little larger hole in it. This is going to make it worse, of course; the bigger hole, you put bigger explosive in it, and consequently the remaining propellant is going to do more damage. This is the worst case; maybe we don't want the worst case.

Capt. Jenkins: The material this morning is packed with such vital information, each topic could take a whole day. If we have any time this afternoon we might get back to some more of these questions. If not, it might be possible to have a discussion group on some particular subject or problem in which you people are particularly interested tomorrow morning if you're not making the tour. We can't dwell any longer on this. Dr. Amster will be up at NOL, we might make arrangements for you people who are going up there. He's going to be at the JANAF meeting next week, and some of you may be there. I do have a little time before lunch, Mr. Saffian.

Mr. L. W. Saffian, Picatinny Arsenal: First, by way of introduction, based on what's been said here in previous talks I feel I should say something concerning this general problem of scaling laws, which is full scale testing. We feel at Picatinny that we've learned quite a bit about scaling laws and in any case, the only way to eventually get away from large scale testing is to continue work on the development of scaling laws. Secondly, I'd like to say that most of the presentations that have been given so far have dealt primarily with the initial detonation or explosion or deflagration or whatever you choose to call it. Our work is essentially concerned with prevention of the second and third and fourth detonation once the first one has occurred.

ESTABLISHMENT OF SAFETY DESIGN CRITERIA
FOR HIGH-ENERGY PROPELLANT MANUFACTURING
AND STORAGE FACILITIES

Picatinny Arsenal is engaged in a broad program aimed at establishment of more realistic safety design criteria for explosives manufacturing and storage facilities. We consider the term "explosive" to mean any material which, under certain conditions, will sustain a high order detonation and is therefore potentially capable of propagating detonation in adjacent systems in which it is contained; consequently we must consider including in this category many of the new high-energy propellants already developed, and those to be developed.

Test methods currently employed for determining sensitivity and detonability of high energy propellants used in our missile systems, and data obtained by these methods, are of value up to a point, but they do not give a complete quantitative picture of the potential large scale behavior of these materials in their actual environments. The usual laboratory tests on sensitivity to impact, heat, and electro-static discharge are useful in indicating to the researcher the general nature of a propellant composition and giving him some idea as to the hazards involved in its handling. Other common methods of testing are based on attempting to detonate the material in question, either unconfined in a cardboard container or confined in a heavy wall pipe, by means of a booster charge or fragment impact. Results of tests of this type, which are conducted with larger quantities of material (roughly 1/4 of a pound to 100 pounds) and under more realistic conditions than laboratory tests, are significant in that they indicate the relative detonability of different propellants in terms of such parameters as minimum

size of booster charge required to produce a stable detonation, and minimum charge diameter (critical diameter) required to sustain detonation. Tests have also been conducted with actual end items (motors with assembled warhead or other high explosive initiator) to determine such factors as order of detonation of the motor, contribution of propellant detonation to total blast produced, and general fragment effects.

Picatinny Arsenal recognizes the value of the aforementioned tests, which need not be detailed any further in this presentation. As a matter of fact a stepwise method for establishing hazard classifications of propellants recommended in one of our recent technical reports[1], is based on such tests. It is essential, however, to recognize, also, the limitations of these tests, particularly where the designer of propellant manufacturing or storage facilities is concerned. In order to fully appreciate these limitations, we must consider the objectives of the designer which are, broadly speaking, the prevention of propagation of explosions and prevention of structural damage in cases where such damage may cause injury to operating personnel and/or very costly equipment. In order to accomplish these objectives in a practical manner (i.e. without resorting to extensive large scale testing) and with confidence, the designer must have at his disposal a reliable basis for quantitatively predicting the large scale behavior of the propellant under consideration in enviroments varying from early manufacturing stages (e.g. a mixing vessel) to the end item (e.g. missiles stored at a launching site). This must be done in terms of such factors as propellant output,

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[1] Picatinny Arsenal Technical Report DB-TR: 13-58; H. L. Partridge; Safety Hazards of Rocket Propellants; November 1958.

sensitivity to blast, and sensitivity to fragment impact, which in turn, determine quantity distance relationships and barricade design criteria for a particular propellant or class of propellants. When considered in this light, it is clear that results of tests such as those previously mentioned cannot be used directly for design purposes, nor can they be used in a design equation. For example, if we establish that propellant X requires a minimum booster charge of 100 grams of tetryl to detonate high order and propellant Y requires a minimum of 200 grams of tetryl under the same conditions, we can say that propellant X is twice as sensitive as propellant Y under those particular conditions, when sensitivity is expressed as minimum size of booster required. If, however, we wish to express sensitivity in terms of minimum blast pressure or minimum kinetic energy required to cause high order detonation, which are major factors in defining quantity-distance relationships, about all we can say based on booster sensitivity is that under the same conditions the pressure and kinetic energy required will be higher for propellant Y than for propellant X; the booster sensitivity ratio of 2 has no quantitative meaning in this respect. In other words, the primary significance of the previously mentioned tests is that they permit gross classification of propellants into such categories as (1) not mass-detonating, (2) mass-detonating under certain very specific conditions only, and (3) mass-detonating over a wide range of conditions, as well as a qualitative ordering of the mass-detonating materials in terms of relative sensitivity. For the designer of facilities involving a propellant which has been shown to be mass-detonating, this is only the beginning.

In line with the previous discussion, the Picatinny safety design criteria program has been divided into three major phases which will now be discussed separately in terms of completed, current, and planned studies.

Phase 1 deals with establishment of realistic quantity-distance relationships for prevention of sympathetic detonation (i.e. propagation due to pure blast effects). The bulk of this work has been completed[2], and has resulted in the establishment of a method for deriving a quantity-distance relationship for any mass-detonating material, to be used for prevention of sympathetic detonation. The general equation proposed is shown in Slide 1, and is based on correlation of available data and relationships reported by various investigators. It has been found to hold fairly well for donor charges of various explosives ranging from 1 to 250,000 pounds in weight. This equation accounts for the various factors in addition to weight, (i.e. degree of confinement, ground reflection, explosive composition, and shape) which affect the peak pressure blast output of a donor charge. This is accomplished by means of the various coefficients indicated which refer the actual donor charge weights to a set of standard conditions. The factor K, therefore, is a constant for each explosive depending only on its sensitivity to blast (i.e. considering the explosive in the role of an acceptor charge). Each K value corresponds to a particular peak pressure which is the minimum blast pressure required to cause sympathetic detonation. It should be noted at this point that the cube root law correlation and the method of donor weight adjustment employed are consistent with the assumption of peak pressure as the criterion of

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[2] Picatinny Arsenal Technical Report DB-TR: 1-59; R. M. Rindner; Establishment of Safety Design Criteria for use in Engineering of Explosive Facilities and Operations-Report No. 1: Sympathetic Detonation; January 1959

explosive blast output. The factor K for a particular material can be determined by a series of small scale tests in which different weights (e.g. 1-100 pounds) of bare spherical TNT charges held sufficiently high above the ground so that ground reflections may be considered negligible (i.e. F_c, F_s, F_e, and F_r each equal 1) are detonated at varying distances from an acceptor charge of the material in question. A logarithmic plot of the maximum distance at which sympathetic detonation occurs versus corresponding donor weight should give a straight line of 1/3 slope, the intercept of which on the distance axis is equal to K. Concerning the donor weight adjustment factors, a considerable amount of information relative to these factors is available in the literature[3, 4] which, although it is based on tests conducted with bursting charge explosives (e.g. TNT, Composition B, Composition C-3), should be largely applicable to mass-detonating propellants (with the obvious exception of the explosive composition coefficient). In cases where coefficients must be determined, or it is desired to check existing methods for calculating coefficients this can be accomplished by appropriate small scale tests. For example, the composition coefficient, F_e, for a new mass-detonating propellant X could be determined by the method outlined schematically in Slide 2.

Slide 3 illustrates what can be done with the proposed quantity-distance relationship for sympathetic detonation. First, it shows a logarithmic plot of the available test data relative to occurrence of sympathetic detonation. The effective donor weights ranging from 3 to 450,000 pounds were calculated by

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[3] U.S. Naval Ordnance Laboratory Report 2986; E.M. Fisher; Explosion Effects Data Sheets; October 1955.

[4] Ballistics Research Laboratory Report 681; T. Sperazza, et. al.; Comparison of the Blast from Explosive Charges of Different Shapes; January 1949.

adjusting the actual donor weights (1 to 250,000 pounds) by the methods previously described. The plotted distance corresponding to any indicated charge weight approaches the maximum distance at which sympathetic detonation would occur with that charge; or, conversely the plotted donor charge weight corresponding to any indicated distance approaches the minimum weight necessary to produce sympathetic detonation at that distance. As would be expected, the plot shows a region in the weight-distance plane where sympathetic detonation has not occurred. A straight line drawn to separate the region of non-occurrence of sympathetic detonation from the region where sympathetic detonation does occur, (i.e. the lowest line) has a slope of approximately 1/3 and corresponds to the equation $d_m = 3.1\ W_e^{1/3}$ and a peak pressure of 100 psi. This is a gross separation based on the most sensitive explosive indicated, i.e. dynamite. Of course, the methods previously described could be used to establish a family of such lines, one for each mass-detonating propellant, depending on its sensitivity. The heavy line shown immediately above the sympathetic detonation boundary corresponds to a pressure of 30 psi and has the equation $d_s = 5\ W_e^{1/3}$, where d_s denotes the proposed minimum safe distance for non-occurrence of sympathetic detonation. This line constitutes, in effect, the application of a safety factor of 1.6 to the maximum distances at which sympathetic detonation can be expected to occur (or a factor greater than 3 based on minimum peak pressure required). Also shown on Slide 3, are the two broken lines $d_s = 15\ W_e^{1/3}$ (uppermost line) representing present intraline quantity-distance regulations for Class 9 and 10 explosives, and $d_s = 9W_e^{1/3}$ representing Class 9 and 10 magazine quantity-distances. A glance at the position of these two lines relative to the sympathetic detonation boundary and the line representing the proposed quantity-distance relationship, indicates

the excessive conservatism inherent in the present regulations, with respect to prevention of sympathetic detonation. Slide 4 lists the equations of the lines just discussed and their corresponding peak pressures. This shows (Item 1) that, according to the data accumulated a minimum peak pressure of the order of 100 psi must be produced at an acceptor charge in order to produce sympathetic detonation (in fact individual values ranged as high as 2,000 psi). This is in contrast to present magazine and intraline regulations, which are apparently based on the premise that minimum pressures as low as 9 psi (Item 3) and 3.7 psi (Item 4), respectively, produce sympathetic detonation. On this basis the proposed quantity-distance relationship (Item 2) is considered to be entirely justified. A comparison of the various equation constants indicates that the proposed quantity-distances represent a 3-fold reduction in present intraline distances and an approximate 2-fold reduction in present magazine distances, even though they incorporate a safety factor of 1.6 as compared to maximum distances at which sympathetic detonation occurred. Furthermore, although present intraline and magazine distances are based on a cube root quantity-distance equation these relationships give no consideration to factors affecting the output of a donor charge other than weight. The significance of this is shown in Slide 5 which is a summary of calculations made by the method previously mentioned to arrive at effective weights of a 10,000 pound donor charge detonated under a wide range of conditions, and corresponding safe distances obtained from the proposed quantity-distance relationship. We have assumed a cylindrical shape for the charge, corresponding to a shape correction factor (F_s) of 1.25. As indicated at the left of the table, various explosive compositions were considered, corresponding to composition correction

factors (F_e) ranging from 1.0 for TNT to 1.27 for H-6. Across the top of the table are assumed correction factors (F_r) ranging from 1.5 to 2.0, for various degrees of ground reflection, and for each of these reflection conditions, correction factors (F_c) ranging from 0.6 to 1.17 for various degrees of confinement are indicated. The calculated values of effective donor charge weights range from 12,500 pounds to 40,600 pounds with corresponding safe distances of 116 feet and 172 feet, respectively. According to present intraline regulations, the explosive weight would be taken as 10,000 pounds and the corresponding safe distance as 400 feet, regardless of the widely varying conditions indicated.

Although our Phase 1 studies relating to sympathetic detonation are essentially completed, some additional refinements would be desirable and are planned for future study. For example, two factors which have yet to be taken into account are (1) effect of acceptor casing on sensitivity and (2) effect of types of ground upon ground reflection (the previously mentioned F_r accounts for height of donor charge above ground but not for different types of ground).

Phase II of our program deals with the effects of fragment impact in causing high order detonation in an explosive charge, and related safety design criteria. A major portion of this work has been completed[6], and has resulted in the establishment of a method for predicting the vulnerability to high order detonation of an explosive system (or vulnerability to mass detonation of adjacent explosive systems) in terms of geometry of the system (e.g. explosive weight/casing ratio, casing thickness) and explosive properties (e.g. output and sensitivity). The method is based on correlation of various relationships developed by British and

[6] Picatinny Arsenal Technical Report DB-TR: 6-59; R. M. Rindner; Establishment of Safety Design Criteria for Use in Engineering of Explosive Facilities and Operations-Report No. 2: Detonation by Fragment Impact; (to be published).

U. S. investigators as a result of theoretical studies, confirmatory tests, and actual experience. Although the actual tests and data relate to so-called conventional ammunition items containing standard explosive fillers (e.g. TNT, RDX/TNT), the relationships which will now be discussed are entirely applicable to the newer high-energy propellant systems for prediction of sensitivity and/or mass-detonability. These relationships, which are detailed in one of our forthcoming technical reports[7], are presented schematically on Slide 6. This shows the factors which must be considered for any explosive system in either a donor or acceptor role. As indicated by equation (1), an output constant (E') must be established for the donor material. Although values of this constant are available in the literature for the well-known explosives such as TNT and RDX/TNT[8,9], values for mass detonating propellants would have to be established experimentally. This could be readily accomplished by a series of small scale tests in which cased propellant samples of various (E/C) ratios are detonated and corresponding fragment velocities measured. The output constant is readily obtainable from a plot of (Vo) vs. (E/C) in accordance with relationship represented by equation (1). The other constant of interest with respect to the donor charge is (B) in equation (2). This equation as represented, is a special case of a general equation which can be used to calculate the number of fragments in any particular weight range produced by detonation of a cased charge.

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7 Op. cit. Picatinny Arsenal Technical Report DB-TR: 6-59

8 Op. cit. NOL Report 2986

9 R. I. Mott, A Theory of Fragmentation, AOR Group Memo 113 (British)

Values of (B) for TNT and various other well known explosives are available.[10] For mass-detonating propellants this value could be determined by a series of small scale tests with cased charges of various geometries, in which fragment patterns are determined and a plot of the data made in accordance with the relationship schematically represented by equation (2). Considering, now, an explosive system which is a potential acceptor, equation (3) indicates that an explosive sensitivity constant (K_f) must be established for the acceptor explosive. As in the cases of the other constants previously discussed, values of this constant are available for some of the well known explosives such as TNT and RDX/TNT mixtures[11]. For a mass-detonating propellant the (K_f) value could be established by a plot of (V_s) vs. f (t_a)(m) in accordance with equation (3). A simple method of obtaining the necessary data would be to fire individual fragments of known mass against propellant charges with various degrees of casing, and determining, for each charge, the minimum velocity of a given fragment required to produce high order detonation.

Some mention should be made at this point, of the critical diameter factor. For the bursting charge explosives (TNT, Composition B, HBX, etc.), this diameter is so small that it generally does not have to be considered in talking about mass-detonation relationships, i.e. any explosive system of practical interest (e.g. shell, warhead, reaction vessel) would have a diameter greater than critical, and therefore be potentially mass-detonating. A high energy propellant, on the other hand, may be capable of high order detonation only when charge diameters are

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10 Op. cit. AOR Group Memo 113 (British)

11 The Sensitivity of High Explosives to Attack by Steel Fragments, ADE Technical Note T2/L9/AVF (British)

relatively large. Of course, if the critical diameter is larger than anything that would be encountered in any in-process or end-item situation, the propellant can be considered to be non-mass-detonating for practical purposes. It may be, however, that the critical diameter of a material is less than diameters encountered in actual large-scale situations, but still large enough to present problems with respect to small scale testing. In most cases of this sort, use of large test charges could be avoided by using small charges which are, in effect, brought above the critical diameter by means of very heavy confinement. For example, in obtaining test data for determination of (K_T) in equation (3), Slide 6, the acceptor charges could be made up of small cylinders of the propellant in question with a thick metal casing (i.e. several inches) around the cylindrical portion but with ends exposed. Plates of various thickness would be butted flush against one end, and fragments fired against these plates in a direction parallel to the longitudinal axis of the charge. The plate thickness would be (t_a) in equation (3).

Once the various explosive constants have been established, and knowing the overall geometry and dimensions of an explosive system, it can be seen from Slide 6 that a reasonably reliable prediction as to its vulnerability to high order detonation by fragment impact (or its potential ability to contribute to propagation of an explosion when considered in relation to any specific environment of adjacent explosive systems) can be made by a straightforward series of calculations. Thus, for a particular donor-acceptor situation, (V_o) and (m) are first calculated. Since the equations are based on the assumption of cylindrical cased charges (i.e. constant cross-section) this will often require consideration of the donor in sections in such a way that equivalent cylinders can be constructed, having average wall thickness, average charge diameter, and the same (E/C) ratio as the actual section. After calculating (V_o) and (m) for each section the corresponding values

of (V_s) are calculated, assuming impact at the thinnest portion of the acceptor casing (i.e. the most severe condition). It is also assumed that the acceptor is in very close proximity to the donor (again, the most severe condition) so that fragments strike the acceptor at their maximum velocity (V_0), i.e. there are no velocity losses which would increase with increasing distance from the donor. As shown in slide 6, therefore, we have established the ratio (V_0/V_s) as a criterion for predicting the gross mass-detonability characteristics of explosive systems, including those containing the newer high energy propellants which are of greatest current interest.

Slide 7 shows a comparison of the vulnerability to mass detonation of a number of standard shell, as predicted by the methods just described, and as stated in the Safety Manual (i.e. whether or not the item is in Class 10). It can be seen that the general agreement is quite good. Furthermore, in at least one of the cases of disagreement, the 240mm shell, it is probable that the predicted result is correct.

The primary objective of our current Phase II studies is very briefly expressed by equation (4), Slide 6, which represents a major refinement of the fragment impact relationships discussed thus far since it would permit calculation of safe distances for prevention of propagation by fragment impact. This work is also aimed at further refinements of the relationship represented by equation (4), such as probability factors (e.g. striking probability of fragments) which would permit reductions in design distances depending on the degree of risk, if any, that can be tolerated.

Phase III of our program, which will be initiated in the very near future, will relate to structural design criteria for barricades, substantial dividing walls, and other protective structures. Some of our thoughts along these lines

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may be of interest. It should be stated, first, that, as might be expected, our studies to date have conclusively indicated that fragment impact, rather than blast, is the major factor influencing the propagation of explosions, and has much more far-reaching effects in this respect. Secondly, blast and fragment effects should be considered separately with respect to their contribution to potential propagation. Correspndingly, the design of barricades, substantial dividing walls, and other protective structures should be based on individual consideration of these separate effects. In view of the relative importance of missiles in causing propagation, barricades should be designed primarily to protect explosives against the impact of missiles (although any resultant contribution of the barricade to blast protection may be incorporated as a further reduction in blast-propagation safe distance). Substantial dividing walls between operating bays should also be designed to protect against missiles but, in addition, should provide the required additional protection against propagation by blast in those cases where two bays must be separated by a distance less than that given by the proposed quantity-distance relationships. It should be noted that these quantity-distance relationships may have to be modified for application to cases where explosive material is distributed within a bay instead of being centrally located since the former explosive arrangement may not represent a true mass-detonating situation. It should be noted that severe structural damage to buildings and facilities may be expected in an installation separated from the origin of an explosion by a distance in accordance with the proposed blast-propagation safe distance, as is borne out by results of studies which indicate that peak detonation pressures of the order of 30 psi (basis for the proposed blast-propagation protection distances) will cause very destructive effects. The major factors to be considered in determining the need for designing to protect against structural

damage are economics, replacement lead time, and personnel exposure. With respect to economics, an installation which would withstand a blast pressure of 30 psi, would be excessively costly to build and might very likely be considerably more than twice the cost of a similar installation which is not designed to withstand such structural damage (i.e., even in the event of complete detonation of the latter installation, its original cost, plus replacement, would be less than the original cost of the installation designed to withstand 30 psi). In extreme cases where very expensive equipment is to be installed in a particular building, the relative cost picture may conceivably change; however, this is unlikely. Of course, replacement lead time must also be considered; however, this should be done as part of establishing a safety factor for production capacity, which, in any case, must certainly be done in designing an installation for explosives manufacture, since it is completely unfeasible to design for protection against severe structural damage at the source of an initial detonation. Regarding personnel exposure, the trend in explosives manufacturing facilities is towards automation and minimization or complete elimination of exposure of operating people. Furthermore, there is every indication that this trend will continue, so that the possibility of injury to personnel will be very remote or virtually nonexistent. It may be concluded from the foregoing considerations that, in general, protection against structural damage should not be included in design of installations for explosive manufacture. In specific cases, however, where protection of personnel and/or costly specialized equipment is necessary, the required degree of protection against structural damage should of course be provided.

In conclusion, we at Picatinny strongly feel that an approach to each specific design case involving high-energy propellant facilities and/or operations, based on the methods discussed in this presentation will result in more meaningful safety design criteria, as well as minimization of requirements for costly large scale testing procedures.

SLIDE 1

QUANTITY DISTANCE RELATIONSHIP FOR SYMPATHETIC DETONATION

$$d_m = KW_e^{1/3}, \text{ where } W_e = F_c\, F_r\, F_e\, F_s\, W$$

d_m = Maximum distance between donor and acceptor charges, at which sympathetic detonation occurs (ft.)

W_e = Weight of a bare, spherical, TNT charge, detonated in free air, which would produce a peak pressure blast output equivalent to that of the actual donor charge (lbs.)

W = Weight of donor explosive charge (lbs.)

K = Blast sensitivity constant (corresponding to minimum peak pressure required at acceptor charge to cause sympathetic detonation)

F_c = Confinement coefficient-Ratio of equivalent bare explosive weight to actual weight of confined explosive (equivalent bare explosive weight is that weight of bare charge which would produce the same peak pressure blast output as the confined donor charge)

F_r = Reflection coefficient-Ratio of equivalent free-air detonated bare explosive weight to equivalent bare explosive weight of the actual donor charges (equivalent free-air detonated bare explosive weight is that weight of bare explosive which, when detonated in free-air, would produce the same peak pressure blast output as a given donor charge)

F_e = Composition coefficient-Ratio of equivalent free-air detonated bare TNT weight to equivalent free-air detonated bare explosive weight of actual donor charge (equivalent free-air detonated bare TNT weight is that weight of bare TNT which, when detonated in free-air, would produce the same blast output as a given donor charge)

F_s = Shape coefficient-Ratio of peak pressure which would be produced by detonation of equivalent weight $F_c\, F_r\, F_e\, W$ of actual donor shape to peak pressure which would be produced by detonation of same equivalent weight having spherical shape.

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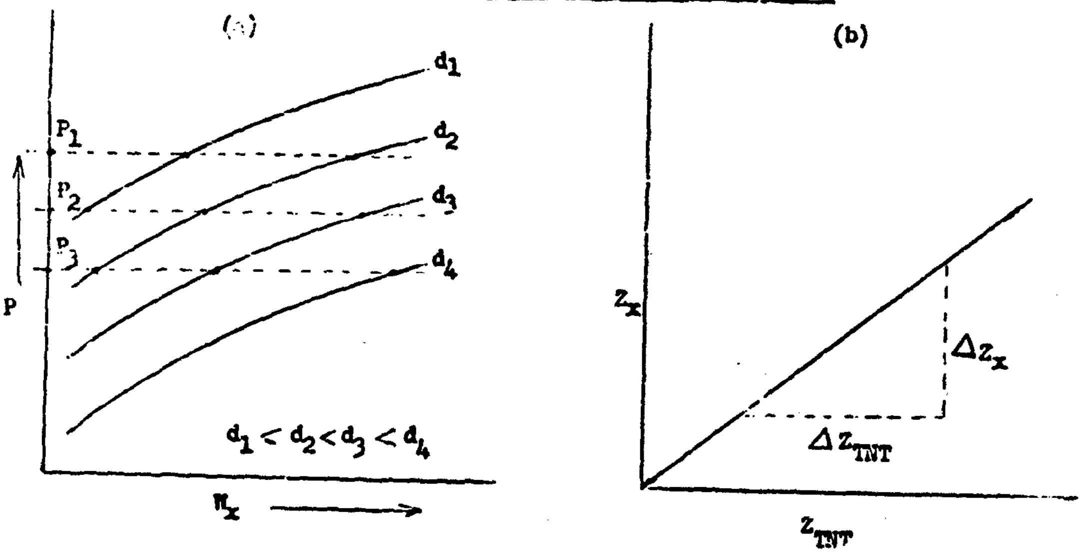
SLIDE 2

DETERMINATION OF EXPLOSIVE COMPOSITION COEFFICIENT, F_c



1. Conduct a series of small scale tests in which different weights (W_x) of bare spherical charges of propellant X are detonated high enough from the ground so that ground reflections are negligible (i.e. F_c, F_e, and F_r each equal 1) and peak pressure (P) measurements are taken at various distances (d) from the detonation source. Plot the data as indicated in Fig. (a).

2. For lines of constant peak pressure obtain the corresponding values of d and W from Fig. (a). Calculate the reduced distance ($d/W_x^{1/3}$) for each point. This should be a constant value for each pressure.

3. For each of the above pressures, obtain the corresponding reduced distance from the Kirkwood-Brinkley relationship for bare, spherical TNT charges detonated in free air[5]

4. Plot propellant X reduced distance (Z_x) against TNT reduced distance (Z_{TNT}) for each pressure as shown in Fig. (b). These points should fall along a straight line passing through the origin. The slope of this line equals $F_e^{1/3}$, or

$$F_e = \left[\frac{\Delta Z_x}{\Delta Z_{TNT}}\right]^3 = \left[\frac{d/W_x^{1/3}}{d/W_{TNT}^{1/3}}\right]^3 = \frac{W_{TNT}}{W_x}$$

[5] Op. cit. NOL Report 2986.

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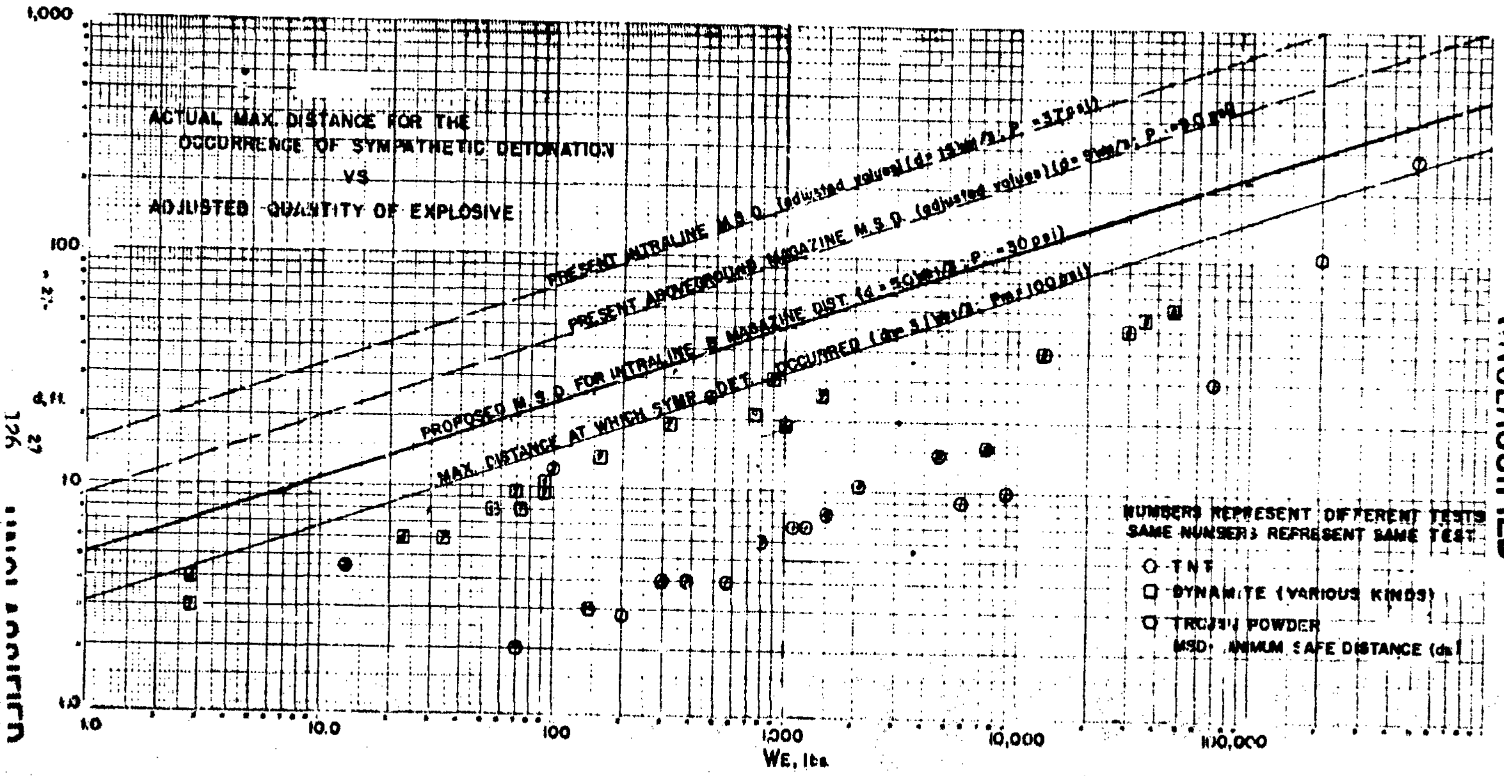
ACTUAL MAX. DISTANCE FOR THE OCCURRENCE OF SYMPATHETIC DETONATION
VS
ADJUSTED QUANTITY OF EXPLOSIVE
PRESENT INTRALINE M.S.D. (adjusted values)
PRESENT ABOVEGROUND MAGAZINE M.S.D. (adjusted values)
PROPOSED M.S.D. FOR INTRALINE & MAGAZINE DIST.
MAX. DISTANCE AT WHICH SYMP. DET. OCCURRED
NUMBERS REPRESENT DIFFERENT TESTS
SAME NUMBERS REPRESENT SAME TEST
TNT
DYNAMITE (VARIOUS KINDS)
TROJAN POWDER
MSD: MINIMUM SAFE DISTANCE
d, ft.
1,000
100
10
1.0
10.0
1,000
10,000
100,000
We, lbs.

SLIDE NO. 3

SLIDE 4

COMPARISON OF PRESENT AND PROPOSED QUANTITY-DISTANCE RELATIONSHIPS

	d (ft.)	P (psi)	Remarks
1.	$3.1 W_e^{1/3}$	100	Maximum distance at which sympathetic detonation occurred
2.	$5.0 W_e^{1/3}$	30	Proposed M. S. D. for intraline and magazine distance
3.	$9 W_e^{1/3}$	9	Present aboveground magazine M. S. D. (adjusted values)
4.	$15 W_e^{1/3}$	3.7	Present intraline M. S. D. (adjusted values)

SLIDE 5

TABLE II

Effect of Various Explosive Weight Correction Factors on Minimum Safe Distance

Assume 10,000 lbs of donor explosive of cylindrical over all shape (F_s=1.25)

Explosive	Reflection Factor / Explosive/Total wt. ratio, β.	(Assumed F_r=1.5) C=0.9 F_c=1.17	C=0.7 F_c=1.04	C=0.5 F_c=0.6	(Assumed F_r=1.8) C=0.9 F_c=1.17	C=0.7 F_c=1.04	C=0.5 F_c=0.6	(Assumed F_r=2.0) C=0.9 F_c=1.17	C=0.7 F_c=1.04	C=0.5 F_c=0.6
TNT	W_e	24,000	21,500	12,500	29,000	25,500	15,000	32,000	28,500	16,300
(F_e=1.0)	d_s	144.0	139.0	116.0	153.0	146.0	122.0	158.0	153.0	127.0
Comp. B	W_e	27,000	24,000	14,000	32,200	28,500	17,000	36,000	31,800	18,500
(F_e=1.13)	d_s	150.0	144.0	120.0	158.0	153.0	129.0	165.0	158.0	132.0
Pentolite	W_e	28,800	25,600	14,900	34,600	30,500	17,800	37,100	34,000	19,500
(F_e=1.19)	d_s	153.0	147.0	123.0	163.0	157.0	131.0	169.0	162.0	134.0
H-6	W_e	30,500	27,500	16,000	37,000	32,500	19,100	40,600	36,200	20,800
(F_e=1.27)	d_s	157.0	151.0	126.0	169.0	1[illegible].0	133.0	172.0	165.0	136.0

NOTE: According to present quantity-distance regulations, d_s for the assumed 10,000 pound donor explosive charge would be 400 feet, regardless of the widely varying conditions indicated above.

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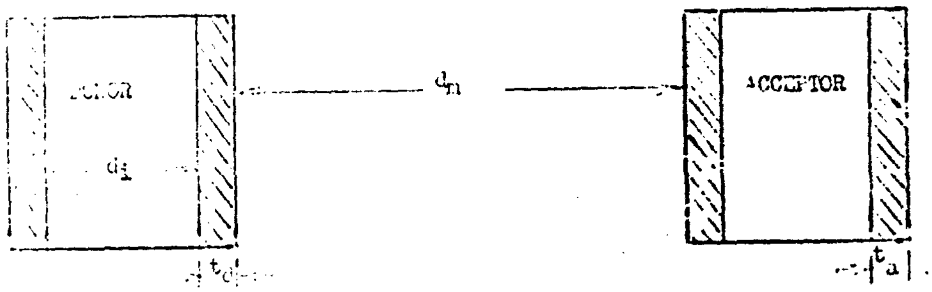
SLIDE 6

[illegible] THEORETICAL DONOR-ACCEPTOR RELATIONSHIPS GOVERNING PROPAGATION BY FRAGMENT IMPACT



$V_o = f\,(E')(E/C)$ - - - - - - - -(1)

V_o = initial fragment velocity
E' = explosive output constant
E/C = explosive/casing weight ratio

$m = f\,(B)(C)(t_d)(d_i)$ - - - - - -(2)

m = mass of largest fragment produced by donor detonation
B = constant depending on donor explosive and casing material
C = donor casing weight
t_d = donor casing thickness
d_i = inside diameter of donor casing

$V_s = f\,(K_f)(t_a)(m)$ - - - - - - (3)

V_s = fragment striking velocity below which high order detonation of the acceptor will not occur.
K_f = explosive sensitivity constant
t_a = acceptor casing thickness

If $\frac{V_o}{V_s} < 1$; detonation by fragment impact will not occur.

If $\frac{V_o}{V_s} > 1$; possibility of detonation by fragment impact exists.

$d_m = f(k)(V_o/V_s)(m)$ - - - - - - - - (4)

d_m = maximum distance from donor charge at which detonation of acceptor occurs.
k - constant depending on fragment shape, air density, and drag coefficient.

SLIDE 7

COMPARISON OF CALCULATED RESULTS WITH SAFETY MANUAL REQUIREMENTS

		Mass Detonation Characteristics	
Item	Explosive	Calcul. Results	Safety Manual
76mm, M42A1	TNT	No	No
76mm	Comp B	No	No
90mm, M71	TNT	No	No
90mm	Comp B	Yes	No
105mm, M1	TNT	No	No
105mm	Comp B	Yes	No
155mm, M107	TNT	No	No
240mm, M114E1	TNT	Yes	No
280mm, T122E3	TNT	Yes	Yes
4.2 in. M329	TNT	Yes	Yes
Rocket head 3.5 in.M35A1	Comp B	Yes	Yes
Rocket head 4.5 in.M32	Comp B	Yes	Yes
81mm, M56	TNT	No	Yes
60mm, M49A2	TNT	No	No

Note: Yes - Possibility of mass detonation occurrence
No - Nonoccurrence of mass detonation

Capt. Jenkins: Mr. Saffian, you said a mouthful. I might add, before I get these questions, the subject of propagation is a vital subject the Board is interested in right now. Positive data is lacking; we don't know how much in the way of quantities cause it. Yesterday I signed a letter establishing a work group, with the concurrence of the Board Members, to review what the Services are doing, review what information we have and try and come up with a coordinated program to get some exact information on this.

Mr. Haite: A lot can be said to get a nice discussion or argument going out. I want to make one mention on philosophy of structures and quantity-distance with respect to buildings. You can take a number of operations and put them in a single building and put a 12" wall between the operations and everyone is happy. You can have 5,000 pounds per bay, or 1,000, or whatever you need in this range and you can have a corridor between these bays, but it's all under one roof. Now if you remove the corridor and remove the roof separating the two walls, then you have two different buildings and you have to move this operation quantity-distance from the other. I think considerable change should be brought about and eliminate this one major problem.

Capt. Jenkins: There is enough in Mr. Saffian's dissertation to keep us all going for a hundred years I think.

Mr. Herman: I would like to clarify one point. On slide 3, your proposed new magazine distance and intraline distance, this was based on your propagation by blast only?

Mr. Saffian: Yes.

Mr. Herman: Where would this have application where you would not have missiles involved?

Mr. Saffian: That's a very good question and what we're driving at here is this. You remember I also said that barricades should be primarily designed against missile effects. What I'm trying to point out here is that once we set up a barricade which will catch missiles, we still have to worry about blast effects which come into play where you have close proximity. If you have two explosive charges very close together, you'll blast heck out of the acceptor. We're not saying that blast is unimportant.

Mr. Herman: But you're saying your blast distance would be so much greater than that required for missile distances to propagate.

Mr. Saffian: I'm not saying that at all.

Mr. Herman: If you put a barricade so that you stop your missiles, then you could bring them down to a certain point but you would still have a minimum distance which you would have to maintain.

Mr. Saffian: For blast.

Mr. Herman: For blast, that's right, but your missile distance would be greater than your straight out-and-out true blast.

Mr. Saffian: The unbarricaded missile distance is far greater than your unbarricaded blast distance.

Mr. Herman: Correct.

Mr. Murphy: These conclusions in your formulas, are they the result based primarily upon your own work?

Mr. Saffian: No, I pointed that out. Our own work is in terms of correlating what's available in literature. So far, as I said, our program is in the early stages. Let me clarify this once again. We haven't run a single test in developing these relationships, but we've looked at an awful lot of data which we feel is good data, and these relationships require quite a bit of refinement. However, the rough conclusions drawn, we think are valid as of now.

Mr. Murphy: Have you been able to look at any accident reports?

Mr. Saffian: Yes, we have locked at accident reports. The trouble with accident reports is that because they are accidents by definition, we don't have all the information.

Mr. Murphy: One further question, have you looked at the recent Nike tests in terms of your formulas?

Mr. Saffian: I think so. Mr. Bishoff, are those the tests we discussed at your office?

Mr. Bishoff: No, when the first reports are ready they will be available.

Capt. Jenkins: That is still very much under study.

Mr. Bishoff: Mr. Haite made what I think appeared to be a very telling point explaining a fault in philosophy in quantity-distance relationships. I feel that I have to give some sort of an explanation as to why such conditions exist. It is true that all of us in the DOD have accepted a one-foot reinforced concrete substantial dividing wall in a building, and that when you have two separate buildings we ask for intraline distance or inhabited building distance as the case may be. But what Mr. Haite evidently doesn't take into consideration is this. The user determines what operations he wants to have in one building by separating the bays by substantial dividing walls. We are not guaranteeing that if you have an explosion in one bay that nothing else in that building will be damaged. We feel that operations may cease entirely in that building. The only purpose of the substantial dividing wall, other than providing some little protection to workers, is to reduce the quantity-distances required to the boundary of the installation

or to other buildings which you want to protect. Again I'd like to say that the user determines how many operations he wants to risk to one explosion. He then puts it all under one roof, but if the user determines that if he loses certain operations he still wants to continue with other operations, then he must have another building at intraline or inhabited building distance.

Mr. Gaylord: Along with peak pressure aren't you considering the effects of impulse also?

Mr. Saffian: We did consider the effects of impulse, obviously all these relationships are empirical relationships primarily, with some theoretical basis, of course. We don't pretend these to be theoretically correct relationships.

Mr. Gaylord: In some instances I think it might be possible to get more damage from the impulse than initial peak pressure.

Mr. Saffian: Yes, particularly where your impulse curve is a shallow curve. In other words, if you don't have a sudden rise in peak pressure you get with most of the explosives like TNT or Comp. B. I think in those cases peak pressure is more definitely the criterion. In some cases where you have propellants, it's quite possible that these relationships should be modified in terms of impulse. In other words, where you would have the same impulses you would have with an explosive but over a longer period of time and with peak pressure. I think that's what you're referring to.

Mr. Gaylord: Yes.

Mr. Saffian: Because we have no data, or as I said because most of our data is on the TNT type of explosive, we've correlated with peak pressure. However, I should say one thing--that in talking about propagation and mass detonation, there's a pretty good indication that these propellants will behave more like TNT or Comp. B so that you will get this very rapid rise of peak pressure for at least many of the formulations under certain conditions of confinement and things of that sort. I'm not sure about the bare charge now.

Dr. Ball: The thing that strikes me most about this presentation is a thought that probably we should change our whole philosophy about barricading, i.e., it's much more important to barricade the acceptor than it is the donor in many cases. Another thing, your comment about how expensive it is to build a structure that will take 30 psi. Maybe you don't need to build that kind of a structure. Maybe you can build a sacrificial structure that will stop the missiles and a light-weight weather protection that won't stop the blast, it'll just get out of the road; it won't contribute anything to the damage to the acceptor. This becomes quite important when you have an operation where you must have an operator or an observer up close. A bomb-proof shelter adequately designed will certainly be safe well within the 30 psi limit. I believe a human body is supposed to be able to stand

something on the order of a couple hundred pounds without a guaranteed fatality and properly designed bomb-proof structures should go into that close proximity to a phenomenon if you need it.

Capt. Jenkins: I don't want to be around with a couple hundred pounds, Doctor.

Mr. Saffian: This comment about a sacrificial structure is precisely what we had in mind, something like one of the "Rube Goldberg" things we've tossed around a little bit--something like these woven blasting mats that you see in construction work. They may be suspended to form a wall which will catch fragments but won't really give you anything with respect to blast protection and it's very interesting to see. I don't recall exactly where I saw this, but it was in one of the EXP reports or the JANAF symposium, I saw a photograph of a British installation where they actually make walls out of mats of this type, rope mats.

Mr. Jezek: Dr. Ball, if you noticed the photographs that we had that Brinkley presented, we did just what you said we should do, we protect the operators but the outside skin where the damage is to be expected, we only put up a flimsy structure, nothing very strong to prevent that.

Dr. C. L. Knapp, Esso Research: We're working with quite a different problem, small quantities in a crowded area where we have to have complete protection for people around and one thing we want to make use of is this woven blast mat. We haven't been able to find out anything about what this blast mat does. First, does it give any pressure relief and second, how does it receive a shock wave. I think it has about 25% openings or something like that. Does the shock wave go through that or does it just bounce back from it and does it give any pressure relief.

Capt. Jenkins: Can anyone answer that?

Mr. Saffian: I couldn't give you a definite answer. I would say that you get some blast relief but I wouldn't know just how much.

Capt. Jenkins: Does anyone have any information on that?

Mr. King: I know this subject came up at the National Safety Council last year and the aircraft missile body makers have done a lot in this respect for testing the missile systems at 2,000 pounds air pressure and things of this sort. I would suggest the appropriate division of the NSC send it to you. I know they use about three layers of woven matting and they find this works effectively insofar as explosions. Insofar as detonations, I don't know, I think they might know something about that.

Mr. J. W. Millin, MMM: On the blast mat situation, we have a high pressure building that uses blast mat on the outside. We were re-examining that building recently for its resistance to these types of things and we hunted

all over the countryside, every blast mat manufacturer, and nobody can tell you a thing about it and nobody knows. They just say well, we try to use so much and that's about all, so I don't think you're going to find any real data on the subject of blast mat anywhere in the country.

Mr. Saffian: In these blast mat installations, has consideration been given in designing these things to make them free to swing?

Mr. E. L. Taton, DASA: Are you prepared to say now or do you have an idea at what variance your current computations are at variance with the published standards we're now using?

Mr. Saffian: What standards?

Mr. Taton: The safety manual standards or the ASESB standards we now use.

Mr. Saffian: There are lots of standards. Which ones?

Mr. Taton: Explosives safety distances for blast.

Mr. Saffian: Yes. I think I said that we are at variance with respect to blast only.

Mr. Taton: My question is, to what extent?

Mr. Saffian: Three times, approximately. I think I pointed that out with respect to distances roughly. That's intraline distances, that's blast only.

Capt. Jenkins: That's blast only, don't be misled. There are other very important factors--missiles. So it's a difference between protection of a building and protection of people.

Mr. Saffian: The OSM does not mention missiles.

Capt. Jenkins: Was that sufficient, Mr. Taton?

Mr. Taton: Yes.

Mr. Buxton: On your Chart No. 6, formula 2 I believe, the one for M which was the largest expected missile, you said that there was pretty good data available on this, but isn't the data with respect to such things as your 155 howitzer projectiles and things of this sort?

Mr. Saffian: I think it was pointed out, this data was obtained with conventional ammunition items.

Mr. Buxton: Really, what good is this formula then when we're considering a mix station which blows and you might take a missile the size of a gear wheel that will fly out or a big chunk of concrete or something, what possible standard do you look to on a thing like this?

Mr. Saffian: You mean like electric motors?

Mr. Buxton: Sure, the whole roof of the building.

Mr. Saffian: That's one of the things we have to determine. However, talking about your mixer, this may not be as important as you might think simply because we're talking here about a minimum velocity requirement. We don't particularly care if this motor or whatever it is strikes an acceptor charge. If it doesn't have the minimum velocity required to cause detonation, it won't initiate the acceptor charge.

Mr. Buxton: Your kinetic energy is $1/2\ mv^2$, the m is still pretty important.

Mr. Saffian: By the same token we think the thing to worry about most right now is the mixer vessel itself; that is, the metal immediately adjacent to the explosive mixture rather than something like an electric motor which is outside this immediate charge.

Mr. Buxton: This is theory strictly, the velocity.

Mr. Saffian: I think they substantiate the fact that the velocity of something like a motor would be much less than the velocity of a fragment which was generated by breaking up the casing immediately surrounding the explosive charge. This $1/2\ mv^2$, the v is square. From this standpoint it is a more important factor although I'll grant you the mass of an electric motor is a heck of a lot more than a fragment.

Mr. Buxton: I may be out of order on this but in one of the mix station explosions we had at Sacramento, we have never taken down our revetment around there, it was a wood-walled earth-backed-up revetment and if you would care to or anyone else you can come there and dig out some real sizable chunks out of the revetment and probably calculate about what velocity the things were moving to go through 12 x 12 timbers, and these were pretty large missiles. They are parts of motors and pretty big stuff, and it went right smack through them and right into the earth a couple of feet. Quite impressive.

Mr. Saffian: I'm sure this would be considered. As I said before, relationships of this sort can only deal with the casing immediately surrounding the explosive charge.

Capt. Jenkins: This is an interesting subject. Dr. Amster?

Dr. Amster: It may be a small point, but you're still depending in these calculations upon mass detonability and you made the statement that for those things for which we don't have the critical diameters, you can add confinement in order to determine these diameters. I think you're being rather optimistic.

Mr. Saffian: Not to determine the diameters, to simulate them.

Dr. Amster: Even to simulate, which means that by the addition of confinement you hope to be able to obtain a detonation. As I say, I think that's being

rather optimistic. Additional confinement, steel confinement for example, is effective only to a small extent in comparison to the diameter of the charge. I certainly don't think you're buying very much with confinement; it helps a little but not a lot. As an example of this, on one of the propellants we tested we knew it didn't detonate at 1½" diameter. We thought that by adding confinement we could help the situation a little bit. We took a steel rod, I think it was 8" or 10" overall diameter, and put a 1½" hole down in the middle of this rod and stuck in propellant and put a big booster on one end and it turned out we had a real nice extruder. The stuff just squirted out the other end. How much bigger confinement are you going to add, 3 or 4 times the diameter of the initial charge? I think that's a rather optimistic hope.

Mr. Saffian: On the other hand, with respect to double base propellants, a lot of tests have been run with actual rocket motors, the actual rocket motor case and also similar tests with uncased propellant grains. The data indicates quite conclusively that all cases of detonation or all cases which reasonably approximate a stable detonation, were obtained with cased charges. This is more or less empirical data and not a result of a specific study aimed at determining.

Dr. Amster: I think that what we're quibbling about here is, as I said before, a matter of what detonation is.

Mr. Bishoff: I think we have a pretty classic example of trying to get a detonation in an explosive sample with regard to ammonium nitrate fertilizer. I believe many years ago at Picatinny Arsenal we used the pipe method of trying to get a detonation in ammonium nitrate fertilizer and by the confinement it didn't work. Then later on we had the explosion at Texas City. Of course, I must say that we knew from other incidents before Texas City, that ammonium nitrate fertilizer could be detonated. The only reason I'm bringing it up is that these lead pipe tests may be a little confusing.

Mr. Saffian: It depends on how thick the wall is, of course.

Mr. Stuckey: I've got a lot of quarrels with quantity-distance tables and barricades and things of this type and I think the problem with us is, we are supposed to be making propellants and not high explosives. We have certain definite problems. I think that some of the old propellant tables are a little short, and I think maybe some of the high explosive tables are a little too long, the distances, but if any of you people have ever been sitting out on one of these lines when it let go, you wouldn't be theorizing someplace because they get awfully rough. I think, actually, these original tables as I understand them, were not put up on theory. They were a study of actually what some of these bad explosions had done. Referring back to Texas City again, they don't always do what theory tells us they are going to do. I will say this, that with all the experiences and studies I've made of the thing, I say those tables have been very good tables for the people who were working out on these lines.

Capt. Jenkins: All of this information is exceedingly valuable to hear and work on in the future, and don't forget we're working on high energy solid propellants today, not to work over the tables.

Mr. Saffian: We say the same thing about the present tables. As a matter of fact, we say it in writing in some of our reports. The only thing we're trying to say is--it's true, these tables are based on actual incidents. It's also true that if they are based on actual incidents, that these incidents will not do just the blast effects. There must have been a lot of missiles and fragments produced during these incidents and yet the tables say that we'll protect you against blast but as far as missiles, we can't help you very much. In other words, these distances are set up and stated as being distances which will protect against propagation due to blast, but not against propagation due to missiles. That's why we're trying to separate the two things. We're trying to say that if it's true that we're protecting only against blast, then you don't need these distances. We also say, not in this case, but in the more detailed presentations, if we're talking about missiles then the present distances go a long way in protecting against both blast and missile. It's only when we're talking about blast that we're really talking about reduction.

Capt. Jenkins: It's too bad you people can't get into some of the discussions and arguments we get into with the tables. You wonder how we support and stand by them. They have stood up pretty well over the years; they are not perfect, and as we gain information we try to bring the rough spots into line.

Mr. Shell Martin, OCE: I think in the philosophy field, I just want to take a minute to remark that we talked about $4,000,000 for tests and talked about guessing this and that, being with an outfit who is more concerned in acquiring real estate for the Services and in building facilities, these test costs and other things are a very minor cost compared with the money that gets thrown down the drain by somebody's educated guessing sometimes. Another thing that I have long thought on the philosophy of the use of barricades, i.e., we should protect the receiving facility and not the doner at that point and this would give us a chance to cut down these tremendous real estate requirements we're apt to get into. These are problems that we're continually faced with and I think there is a certain distance when we get to a certain quantity of explosives where of course the missiles are going to travel to this site faster than the blast wave, so even though we have a barricade that the blast wave may take over, we have slowed up our missiles until we don't get a detonation from the missiles and the blast wave comes along--we don't have to have a barricade that's going to stand there and take all the blast. I don't say this is true; it is well worth studying. The other thing is, when we talk about structural damage to facilities off some place else, intraline or off the reservation, several comments have been made in regard to stating that we could look at this as mainly the peak pressure. When we are dealing with the larger quantities of particular propellants and those getting closer to a high explosive in their reaction here, when we are considering a structure and how much blast

it takes to knock it down, peak pressure is very faulty. We have used that for years; it's very faulty stuff. We have to not only consider the peak pressure, but we have to have a combination in our analysis and take a dynamic type of equation which includes the length of the impulse or of our overpressure and the total energy in the blast wave.

Mr. Saffian: This peak pressure is only used insofar as a criterion for sensitivity is concerned. I just wanted to point out that this peak pressure business is in no way related to what's important in knocking down a wall, only what's important in starting a detonation.

Capt. Jenkins: Any more questions? Mr. Foster.

Mr. J. S. Foster, Rohm & Haas: At the Redstone Arsenal Division of Rohm & Haas, research and development work on new explosives and new solid propellants is conducted. Because of the experimental nature of the work, it is necessary to assume that detonations will occur and to provide protection for our personnel against the effects of a detonation. In order to provide the required personnel protection, it was necessary for us to do some work on the effectiveness of personnel shields. This morning I shall discuss the results of our studies on the effectiveness of reinforced concrete against the detonation of pound quantities of explosives and the effectiveness of transparent safety shields against the detonation of gram quantities. I will discuss our results on the effectiveness of concrete first. We first became interested in the problem of the resistance of concrete to blast in the design of a facility for the manufacture of small quantities of experimental explosives. A number of trips to explosives manufacturers revealed that there were few data that were directly applicable to our particular problem. Many of the installations did not attempt to provide personnel protection because standard explosives only were manufactured, or because it was considered impractical with the large quantities of explosives handled. At the installations which did attempt to provide personnel protection, there did not appear to be any systematic approach to the problem. The required thickness of concrete to protect against a given quantity of explosive was left to the judgment of people with long experience in the field. A literature search was also made and here again there was little information that was pertinent to our problem. The one reference we found that appeared to be applicable was a report entitled: "Fundamentals of Protective Design," published by the Corps of Engineers. This is a report on the procedures used by the Corps of Engineers for the design of fortifications to protect against artillery and bombs. Included was a chart showing the damage which would be sustained by a reinforced concrete wall subjected to the blast from a detonation. (showed slide) This chart is shown in the first slide. The ordinate is the ratio of the thickness of the concrete to the one-third power of the weight of explosive and is a measure of the strength of the concrete wall. The abscissa is the ratio of the distance from the explosive to the one-third power of the explosive weight and is a measure of the force acting on the wall. These lines are lines of constant fictitious fiber stress. The predicted damage corresponding to each of these fiber stresses is shown here. You have zones of fine cracks, light scabbing, heavy scabbing,

1" to 4" cracks and complete failure. The correlation between these fictitious fiber stresses and the predicted damage was based on a series of tests made on reinforced concrete beams. When using the chart, it may be necessary to make certain corrections. The explosive assumed in the derivation is TNT. If other explosives are assumed, it is necessary to correct the weight of explosive. The Corps of Engineers recommends that the correction be made on the basis of relative peak pressure for the same conditions. The chart also assumes a compressive strength for the concrete of 4000 psi and sufficient reinforcing steel to provide tensile strength corresponding to the compressive strength of the concrete, and to knit the wall together. If the compressive strength of the concrete is less than 4000 psi or if insufficient reinforcing steel is used, it is necessary to use corrected distance from the explosive center to the wall. To us, this chart appeared to provide a possible method for determining the extent of damage to concrete walls exposed to a detonation. However, since the assumptions made when developing the chart did not necessarily apply to our problem, we decided to conduct a few tests to determine the validity of the chart for our problem. The tests we made were designed to yield information on our specific design problem and to check the applicability of the correlation shown on the chart to small quantities of explosives, up to approximately 25 pounds, located fairly closely to the wall, i.e., within 3' to 5' from the wall. The results we obtained from these tests are shown in the next several slides. (slide, 12" wall-before tests) The original test set-up is shown in the next slide. It was desired to test different types of single and double wall construction as well as testing the effect of the blast wave. Because of this, we used the arrangement shown here. The double wall on the left of the slide, which I will call Wall "A" for convenience, was made up of two completely independent 12" thick concrete walls separated by a 3' air gap. The reinforcing steel in these walls was twice that called for in the OSM for substantial dividing walls being 1/2" bars 6" on center, EWEF. The inner portion of Wall "A" was poured monolithically with the other inner walls and tied lightly to its neighbors with reinforcing steel. Wall "B", the next clockwise from Wall "A", was identical to Wall "A" except that earth was packed between the two halves of the wall. Wood planks were used to retain the earth at the sides of the wall. Wall "C" differed from "B" in that the two halves of "C" were tied together at the top with three concrete beams, the two outer beams containing four 1/2" steel bars, and the central beam being unreinforced. Wall "D", in the foreground of the slide, was reinforced with twice the steel of the others, having 1/2" bars 3" on center, EWEF. In addition, half of the wall was faced with a 3/8" thick steel scab plate firmly anchored in the concrete. As can be seen in the photograph, Wall "D" was the only single wall of the four. The concrete used here was nominal, 3000 pounds, and was allowed to cure 28 days before the test. Test cylinders poured with the walls showed a strength of 3200-3500 psi after 28 days. The conditions for the first test were a charge of 3.1 pounds of nitroglycerin located 2.5' from each of the facing walls and 2.5' from the ground. These conditions were calculated to yield a blast pressure equal to that given by 25 pounds of nitroglycerin at a distance of 5', the actual conditions in which we were interested. (slide, 12" wall after 3 pound nitroglycerin) The damage

caused by the 3.1 pound charge of nitroglycerin is shown in the next slide. This charge caused relatively little damage to any of the walls. Fine cracks, as shown here, were formed at each of the corners, but there was no evidence of failure at the center. A crack was also formed at the junction of one of the outside beams and the outer portion of Wall "C." (slide, 12" wall after 3 pounds nitroglycerin) The next slide shows another view of a corner crack. Separation between the earth fill and the inner portion of Wall "B" can also be seen. It appears that Wall "B" bent elastically during the detonation. This test showed that any of the construction designs chosen would be satisfactory for the condition of 25 pounds of nitroglycerin located 5' from the wall. However, since the structure was still relatively sound, we decided to continue the tests to obtain more definitive results. The conditions for the second test were 6 pounds of nitroglycerin located 2½ ft. from the face of each wall. (slide, 12" wall after 3 and 6 pounds of nitroglycerin). The damage from this test is shown in the next slide. The results obtained were similar to those obtained from the first test. The existing corner cracks were increased and a second concrete beam on Wall "C" was cracked. No damage was done to the central portion of the walls directly opposite the charge. The conditions for the third test were 12 pounds of nitroglycerin located 2½ ft. from the face of each wall. (slide, 12" wall after 3, 6, and 12 pounds nitroglycerin). The damage from this test is shown in the next slide. This shot resulted in considerable loss of concrete at the wall corners and fine cracks in the center of Wall "A". Although it is not visible in the slide, fine cracks were found in each of the inner walls. For the fourth test, we used 25 pounds of tetryl, which is equivalent to about 16 pounds of nitroglycerin and a corrugated roof. (slide, 12" wall after 3, 6, and 12 pounds nitroglycerin and 25 pounds tetryl). The next slide shows the structure after this shot. The inner half of Wall "A" was tipped away from the blast, but the central cracks which were formed after the 12 pounds nitroglycerin test were hardly enlarged. This failure to enlarge the cracks apparently was the result of the earlier failure of the corner reinforcement, so that the wall was free to move as a unit. The outer half of Wall "A" was entirely undamaged. Wall "D" in the foreground here suffered the most damage of the four, in spite, or because of containing about twice as much steel as the others. The half covered with the scab plate was virtually intact (although tilted) except for the concrete loss at its corner with Wall "C". In contrast, however, the other half was almost completely destroyed, with missiles flung up to 20 yards from the wall. (slide, 12" wall-west side after fourth shot) Another view of the structure is shown in the next slide. The inner half of Wall "B", backed up with earth, was broken into two pieces with substantial loss of concrete from the steel of the smaller piece. Enough pressure was transmitted to the earth fill to burst out the retaining boards and give the outer wall a slight, permanent cast. The corner between "B" and "C" lost concrete only on the inside down to the steel, and was the least damaged of the four corners since it was backed up on both faces with earth. (slide, 12" wall-east side after fourth shot) A third view of the structure is shown in the next slide. The inner half of Wall "C" was the least damaged of the four inner walls, showing fragmentation only at the edges. Although it was nearly plumb, the outer wall had a list of about five degrees. All three of the

two the beams failed, but no serious spalling occurred on the outer wall opposite the beams. Again the pressure on the earth fill burst open the retaining boards. From the results of these tests, it is possible to draw a number of conclusions. When considering double-wall construction, the design of Wall "A" was clearly superior to the others. It appears that the dirt fill serves no useful purpose and has the disadvantage of transmitting the force to the outer wall. The use of a double wall separated by an air gap, with one wall considered sacrificial, appears to offer considerable possibility as a method of obtaining protection against relatively large quantities of explosives without having to use very massive concrete walls. The advantage of a sacrificial wall is due to the fact that it requires a great deal more energy to destroy a wall than simply to spall the wall. It also appears that the walls should not be tied substantially at the corners, but rather left free to move as a unit. The great advantage of an integrally-cast steel scab-plate was clearly demonstrated. Because of this result, we have used steel scab-plates in a number of locations. Since we still had two undamaged walls left, we decided to continue the tests. The next test was designed to test the effectiveness of a single 12" concrete wall against blast. The undamaged portion of Wall "A" was used for this test. For the first shot, 15 pounds of nitrostarch was detonated 3' from the wall. Since the damage was relatively light, this shot was followed by two more of 27 pounds each of nitrostarch. (slide, 12" wall after nitrostarch tests) The wall as it appeared after these tests is shown in the next slide. The only damage to the wall was the formation of fine cracks in the center opposite the charge. These cracks actually appeared during the first 15 pound detonation, and they were scarcely enlarged by the subsequent large detonations. There was no scabbing of the opposite face in any of the shots. The last test in this series was made to test the effectiveness of an anti-scabbing device. Although the effectiveness of a 3/8" steel scab-plate heavily anchored into a concrete wall had been demonstrated, it was uncertain that such a plate could be attached to a wall already in existence and prove equally effective. When an application in our operations arose in which an anti-scabbing device was desired but not available, we used the undamaged 5" wall to test the effectiveness of a heavy rope blanket in containing spalled concrete fragments. For this test $8\frac{1}{2}$ pounds was detonated 6" from the face of a 5" wall. (slide, 5" wall after $8\frac{1}{2}$ pounds) The next slide shows that this charge was very effective in producing the required fragments. (slide, rope blanket) The next slide shows the rope blanket after the shot. The blanket had been suspended loosely behind the wall, and it successfully contained essentially all of the fragments produced by the blast although the blanket was torn from its support. As the slide shows, the strands were stretched and parted to a certain extent, but none was severed. A cardboard witness-plate, which backed up the rope blanket, showed that few particles actually penetrated the blanket. From this test, it was concluded that a heavy rope blanket could be used to contain particles where scabbing of the concrete wall was the maximum damage expected. (discussion of chart and test results) The conditions which were tested were plotted on the Corps of Engineers chart. This is shown on the next slide. Points 1, 2 and 3 represent the conditions specified by the OSM for the protection of personnel. The conditions for point 1 are 12" of concrete

and 15 pounds of explosive located 3' from the wall. The conditions for point 2 are 30" of concrete and 50 pounds of explosive located 3' from the wall. Point 3 is for a 36" wall and 70 pounds of explosive located 3' from the wall. The remainder of the points represent the conditions tested. Before plotting these points, the weight of explosive was corrected to its TNT equivalent.

TESTS ON RESISTANCE OF CONCRETE TO BLAST

Point No.	Explosive	Wt (Lbs)	TNT Factor	Wall	Steel	Dist (Ft)	Test Results
1	? OSM	15	(1)	12"	½ at 12	3	-------
2	? OSM	50	(1)	30"	½ at 12	3	OSM standard for personnel protection
3	? OSM	70	(1)	36"	½ at 12	3	-------
4	Nitrostarch	15	0.9	12"	½ at 6	3	Fine cracks
5	Nitrostarch	27	0.9	12"	½ at 6	3	Fine cracks
6	Nitroglycerin	7.7	1.4	5"	½ at 12	2½	Heavy scabbing
7	Nitroglycerin	6	1.4	12"	½ at 6	2½	Corner damage only, center intact, no cracks
8	Nitroglycerin	12	1.4	12"	½ at 6	2½	Minor central cracks, no spalling
9	Tetryl	25	1.3	Weak-ened 12+ 3/8" plate	½ at 3	2½	Scab plate intact, bare wall showed very heavy spalling
10	Propellant	8.5	(1)	5"	½ at 12	½	Wall perforated with 18" diameter hole, rope blanket held fragments

From these results, it appears that the damage predicted by the chart is greater than that actually obtained. Based on these results, we have decided to use this chart to give an indication of the damage that could be expected from a detonation. We currently use the chart only for those conditions represented by the central portion since this is the area covered by our tests and is also the region of current interest. We consider that the shaded area provides adequate personnel protection if a steel scab-plate is used to prevent spalling or a heavy rope blanket is used to contain the

concrete fragments. The area above the dotted line is used for a bare concrete wall. From the number of tests we have run, I believe it is obvious that we have only "scratched the surface" on this problem of the resistance of concrete to blast, and that more extensive tests are needed. This is particularly true for the conditions represented by the ends of the chart. We are now using the chart for the simple reason that it is mandatory that we have some method for determining concrete resistance and this chart represents the best information presently known to us. We feel that the technique used by the OCE in constructing the chart is applicable to the problem of detonations close to the wall, and if additional tests could be made, it is possible that this technique could be developed into a very useful and generally applicable method for determining the protection afforded by concrete walls exposed to high peak pressures.

Mr. Buxton: Were your reinforcing rods welded together?

Mr. Foster: Yes.

Mr. Buxton: Was it a single or double weld?

Mr. Foster: Double.

Mr. Endsley: What is the depth of spalling inside the cubicle?

Mr. Foster: I don't know. It is just a matter of an inch or so.

Mr. Bishoff: Did you have reinforcing rods on the interior of the wall?

Mr. Foster: I can tell you a little later. I can check the drawing.

Mr. Marsh: It looks as if there is only one wall.

Mr. Foster: That is what it looks like. I didn't run these tests myself--

Mr. Herman: What was the weight of the charge?

Mr. Foster: 25 pounds of tetryl.

Mr. Bishoff: What was the scab-plate and how was it welded?

Mr. Foster: 3/8" scab-plate and welded to the reinforcement. Incidentally, this wall also contained twice as much reinforcement as the other walls.

Mr. Bishoff: How long had the concrete cured before you exposed it to the first test?

Mr. Foster: It was 3000 pound concrete and we let it set 28 days. We got tests between 3200 and 3500.

Mr. Endsley: Why do you switch from tetryl to nitrostarch?

Mr. Foster: I think John Hindle ran these tests and I think he had nitrostarch handy at the time. I would now like to turn your attention to the results of our studies on transparent laboratory safety shields. As a part of our research activities, new high-energy compounds are continually being synthesized. Many of these compounds are unstable and will detonate under the slightest provocation. Since, of course, the stability of a compound is not known until after it is synthesized, it is necessary to assume a detonation almost every time an experiment is run. Because of this detonation problem and because in a chemistry laboratory it is necessary to change experimental set-ups rather frequently, there existed a need for a relatively light, transparent safety shield which would protect personnel against the effects of the detonation of small quantities of explosives. Experience had shown that commercially-available laboratory safety shields did not provide the necessary protection. A search of the literature revealed that here again there were few data that were applicable to our problem. Because of this, we decided to conduct tests on a few materials in order to develop a suitable shield. Transparent materials selected for testing were plexiglass, safety glass, and glass containing a wire mesh. The test procedure was to clamp the material to be tested in heavy angle-iron frames. The charge of explosive was placed in a glass bottle and suspended at a known distance from the shield. Charge weights used varied from 5 to 50 grams of Comp. C-4 and the distances varied from 6" to 30". A shield was judged to have failed if a fragment penetrated the shield, or if it splintered on the side away from the blast, or if it split, cracked, bulged, or broke to the extent that there was an open space between the surfaces. If none of these conditions were obtained, the shield was assumed to offer adequate protection. Preliminary screening tests revealed that the three materials selected for testing gave about the same degree of protection. Since plexiglass was easier to work with than glass, it was selected as the shield material. The next step in the program was to determine relation between the quantity of explosive, the distance from the shield, and the thickness of the plexiglass. The results we obtained are shown in the next three slides. (slide, $\frac{1}{4}$" plexiglass) This slide shows the results we obtained for $\frac{1}{4}$" plexiglass. It is a plot of the weight of the explosive as the ordinate and the distance from the shield as the abscissa. The weight goes from 0 to 50 gram and the distance goes from 0 to 30". The circles signify protection and the X's signify failure. In general, more than one test was made at each condition. From this chart, you can see that rather large distances are required to provide protection against more than 5 or 10 grams. Since, because of the standard size of lab benches, it is not practicable to use distances over about a foot, $\frac{1}{4}$" plexiglass is not satisfactory for quantities over about 10 grams. From the chart you can see that there is some scatter in the data. For example, you may get a protected point and then a series of failures for increasing distance. This scatter is believed to be due primarily to the variability of the fragments. We found that the major cause of the damage to the shield appeared to be due to fragments rather than the blast wave. If the shield is tested under fragment-free conditions, the distance required for protection against a given charge is reduced. Alternatively, if steel fragments are generated, there is considerable question as to whether a transparent safety shield can be used to provide the required protection. Since

glass fragments are the most common in a laboratory, the bulk of the tests were made with glass fragments. (next slide) This slide gives the results of the tests on 3/8" plexiglass. The ordinate and the abscissa are the same as before, weight of explosive and distance of the charge from the shield. From these results, you can see that 3/8" plexiglass could be used to protect against approximately 25 grams and still fit on the lab bench. (next slide) This slide gives the results of the tests on ½" plexiglass. ½" plexiglass can also be used to protect against 25 grams, but the distances required for protection against 50 grams are still quite large. It was also found that for 50 grams of explosive, movement of the shield becomes a problem. Unless a very heavy shield is used, it is necessary to tie the shield to prevent excessive movement. Based on the results of these tests, it was decided to standardize on two shields, one shield to protect against 5 to 10 grams, and one shield to protect against 25 grams. (next slide) The next slide shows the light-duty shield. The shield is composed of ¼" plexiglass sheet in a frame of welded aluminum channel. Cork gaskets are used to prevent stress concentration. This shield weight is 21¼ pounds. (next slide) The next slide shows the medium-duty shield. This shield consists of ½" plexiglass sheet, also in a frame of welded aluminum channel. This shield weight is 30 pounds. The shield is made in a "V" shape to provide some degree of side protection. The plates you see in the center are access openings for the installation of a manipulator to turn stopcocks. It was decided not to provide, at this time, a shield suitable for 50 grams. A suitable shield for 50 grams can be provided, but the weight becomes excessive, and for the present we do not have a need for a 50 gram shield.

Mr. Saffian: Have you considered buticite-cord-lucite in your tests?

Mr. Foster: No. We didn't consider it. We saw your results on that, and for reasons I don't know about, we selected plexiglass.

Mr. Buxton: Did I understand you to say that the shield material was in a frame?

Mr. Foster: The shield material was in a frame--a heavy frame.

Mr. Buxton: But it could not move?

Mr. Foster: That could very well be, because--

Mr. Buxton: This could have a tremendous effect on the force if it was not stationary.

Capt. Jenkins: The missiles would get there first.

Mr. Foster: That is right. We ran our final tests on this actual set-up that is shown here, and they did protect the points over five or eight tests. We also made some high-speed movies to see how fast the shield did move and it was a very slow movement. The 25-gram shield will tilt over under the 25 grams.

Mr. Buxton: This would answer my question. Was the shield moving before it got hit with the missile?

Mr. Jezek: Did I understand you to say that you were transporting explosives in your lab in glass containers?

Mr. Foster: No. That is a whole different subject. This is the actual synthetic set-up that we have for synthesizing the chemical, and the reason for selecting glass fragments is to simulate beakers and such things as that.

Mr. Stuckey: We made some pretty extensive tests of high explosives on plexiglass. We never considered those real thin sheet, we used 1". We blew two tetryl boosters under this one time which produced both heavy, metal fragments and about a tenth of a pound of explosive. We never had any trouble holding them, but once we had had an explosion in it, if you put a second charge even half that size in it, it fragmented and blew up. Now, the heat of an explosion has a lot of effect on the plexiglass--evidently it does something to it.

Mr. Foster: Did you say that we have trouble with steel fragments?

Mr. Stuckey: No, but we also managed to hold the five pounds of tetryl with glass too.

Mr. Buxton: This is a little off the subject as you presented it, but do you know anything about the effect of dilution systematically? One can tell how much protection he gets by working in a dilute solution?

Capt. Jenkins: I didn't hear that.

Mr. Buxton. I asked about the effect of dilution. In other words, we are making a chemical for the first time and we would like to protect ourselves by working in a dilute solution. That is quite frequently possible. What I'm wondering is if there is any systematic way of getting any idea of how much protection you could obtain by doing so.

Mr. Foster: I don't know. The procedure we use is to consider that you get no reduction in force.

Mr. Buxton: I think some other people are using this principle, but they won't have trouble if it's diluted with 50% solvent or something like that.

Mr. Foster: That it would not be likely to detonate in that case. Is that right?

Mr. Buxton: Oh yes, it is surely to burn.

Mr. Foster: See, the thing is, we are assuming a detonation. We don't know if it will or it will not.

Capt. Jenkins: Dr. Ball, would you like to add something to that?

Dr. Ball: I think maybe you've got the answer on that. If the stuff is actually in solution, you're not going to get a detonation. However, if you've got a suspension there, you might still have trouble.

Mr. Murphy: The manipulating apparatus that you referred to when you pointed out the access hole. What material is it made of?

Mr. Foster: It is steel.

Mr. Murphy: Did you run any of your tests with the manipulators?

Mr. Foster: We ran with the manipulators and it did come out.

Mr. Brinkley: Mr. Foster was talking about--and Mr. Saffian commented on--this is a cord-buticite. I'd like to inform all personnel here that Picatinny Arsenal published five technical reports on the use of cord-buticite in relation to barricade, because they have more problems up there than, I believe, any installation in the country, relative to detonators, tetryl, lab works, and operations involving explosives. If any person here is going to do any lab work that requires operational shields, I think those reports are a necessity, if you want to protect your personnel. If I'm not mistaken, I think cord-buticite is made by Rohm & Haas. It is very expensive, and I don't think you people need that much protection down there at Rohm & Haas in your lab in the quantities involved. I agree with you on that point.

Dr. Amster: You did some work at Rohm & Haas on safety glasses. What kind did you finally decide best to be used? Do you know about that?

Mr. Foster: Yes. That, incidentally, has been published. We use a mine safety appliance called "soft side goggle". The information from the tests we made is this: we tested a whole series of goggles using a department store manikin with cotton to simulate the eyes, and we would take a rocket motor and let the flame from the motor actually go right into the face. Then we would check it to see if the cotton was scorched or anything. We did this from face and on the side. From the results of these tests, we found that this mine safety appliance soft side goggle was the best one. You can get the same protection with rubber goggles or acid goggles, but those are uncomfortable. Normal safety glass and little visors and things like that will not give you the same protection.

Capt. Jenkins: Mr. Jezek informs me that Mr. Burnieburg from Mine Safety Appliances is here today. Anyone who wants to know more information on safety goggles, Mr. Burnieburg could, no doubt, answer your questions privately if you want specific information on it. Mr. King?

Mr. King: Getting back to this morning's work on the cubicle construction-do you recall the pressure calculations that you had made for the 3 pound charge? I think it was 18" from the wall, or was it 3'?

Mr. Foster: It was 2½' from the wall.

Mr. King: What pressures do you think you had against the wall?

Mr. Foster: It is not included.

Mr. King: The reason I asked was that we had made some tests that indicated that the ordinary 1' wall would only be good for 12 to 24 pounds I believe, based on the impulse from the charge of about 3 to 5 pounds.

Mr. Foster: The pressures we are talking about are up in a range quite high, much higher than 30 pounds psi that we were talking about before.

LtCdr Buckles: As a matter of interest, in our igniter preparation building in the cast area, we use 3/8" plexiglass shields. As a result of an inspection that was made down here, it was recommended that we run a test. In the test, we erected a 3/8" plexiglass shield that was supported at the top and the bottom, and we used 150 gram igniter intact, placed three inches from this plexiglass and we let fly. All we did, I think, was to slightly crease and discolor the plexiglass. We had no penetration whatsoever. This is a point of interest.

Capt. Jenkins: Thank you very much, Cdr Buckles. Mr. Molloy, who is the Astrodyne representative, has the next item on the agenda.

APPLICABILITY OF EXPLOSIVE SAFETY MANUALS TO

CONSTRUCTION AND OPERATION OF A SOLID PROPELLANT PLANT

By J. J. Molloy

No single factor exerts more effect upon a solid propellant operation than the safety procedures under which work is performed. The objectives of safety are well understood, but the impact of safety measures themselves tends to be underestimated by persons unfamiliar with industrial operations. Like the iceberg, only a small fraction of the total safety picture is visible to the casual observer.

The Ordnance Safety Manual (T.O. 11A-1-4- and ORD M7-224) is our major regulatory explosives safety publication and contractural obligations require us to closely follow the Manual as a standard for safety in the construction and the operation of a solid propellant plant, although it, the Manual, is in some areas omissive and inapplicable for the production of solid propellants. For instance, in some cases research and development needs for solid propellants are not recognized at all, in others they are covered only in part. This lack of standards or guidance peculiar to our needs creates adverse situations wherein the contractor's progress and production are delayed during the long time consuming processes of obtaining official sanction of some operational development not specifically covered by the Manual.

Let me review some of the problems currently experienced along these lines. When our plant was conceived, the original objective was to produce a low-cost propellant. It was realized that to accomplish this end, it would be necessary to exercise a high level of judgment in the field of explosive safety. The most fundamental viewpoint expressed by all concerned during the building of this plant was that all planning, policies, and application or interpretations of safety regulations would be based upon a constructive analysis of actual need, rather than upon a rigorous application of safety practices and regulations developed for use in ordnance shell loading plants and high explosives works.

As an example of the use of judgment in producing low cost propellant versus literal application of regulations, we have this situation: An R&D aging study of 15 pounds of ammonium nitrate propellant requires six weeks exposure to 70°F at 30 grains of moisture. These conditions are available in one service magazine, at conditioning facilities in our test area, and in our operating buildings. Yet, literal interpretation of the Manual does not allow the performance of this small aging study in any of these facilities because it violates the intended usage of them. Is, then, compliance with regulations, in such a minor matter where no appreciable increase in hazard is created, so important as to justify the construction of a new dehumidified and controlled temperature area, merely to conduct occasional, small R&D aging studies? We think not, however, our opinion is defeated by the application of regulations.

Numerous agreements were reached in joint conferences of military and the contractor regarding a set of ground rules for the operation of the plant. It is significant to note, during this period, the Ordnance Manual was used as a guide, but its requirements were tempered by the judgment of the safety groups involved.

Subject to these agreements, the task was the design of a Pilot Plant and Manufacturing-Control plant for composite propellant development. Two primary objectives were: (1) To construct a versatile development facility, capable of handling any of the known composite rocket propellants, including Class 9 explosive materials, (2) To lay out an efficient manufacturing line in a manner consistent with logical explosive safety practices. To achieve these objectives, a staff of supervisory and technical personnel were recruited who could offer a background of direct and substantial experience in propellant and explosives manufacture, or in the fabrication of items requiring explosive components. They were apprised of the agreement that the traditional rules and regulations developed for explosives works and shell loading lines under Ordnance Corps jurisdiction were to be followed judiciously, not blindly. The result of their work embodied the principle of assuring adequate safety without unduly sacrificing efficient, low-cost operations.

Plans for the Pilot and Manufacturing-Control plant were reviewed and it was agreed the proposed layouts did not follow a literal interpretation of the Ordnance Manual. The plans were accepted without material change, however, and it was agreed that good judgment had been applied in the solution

of the problem. However, as time went on there became a grey area in safety concept due to the rapidly changing field of solid propellants. These changes in safety requirements seriously hamper planning of proposed development operations, delay scheduled work, and greatly increase the cost of operating the solid propellant plant.

The importance of effective safety measures in the operation of a plant is obvious. Every industrial plant is potentially hazardous, and these hazards are magnified where operations involve explosives. But this is not the same thing as saying that a safety procedure need be published for every detail of every process. Common sense argues for employing practical safety measures tailored to the requirements of specific situations. For example:

A. In our research laboratory rooms there are hundreds of pieces of scientific equipment such as spectrophotometers, spectrographs, micromerographs, viscometers, calculators, balances, calorimeters, etc. The quantities of propellant tested in this equipment is very small. This equipment is to our knowledge available only with general purpose electricals--general purpose electricals that, in some cases, are not available with Underwriters Laboratories' approval. Following Paragraph 103.b. of the Manual, it is necessary an exemption be prepared, which entails listing and justifying individually each piece of this scientific equipment, from Paragraph 602 of the Manual. Since the use of such general purpose electrical equipment with small quantities of propellants in research laboratories seems common in solid propellant industry throughout the nation, it is felt that the processing of this complex exemption serves little purpose. It adds no safety control or improvement. Regulations regarding research laboratories are not mentioned in the Manual. With new and expanding laboratories in the industry it seems that they should merit recognition, if they are to be subject to military explosives safety regulations.

B. There are many opinions, which due to varying interpretations of the Manual (particularly Paragraph 250), causes confusion, inconsistency, and lack of a guiding principle as to the type of personnel protection (operational shielding) needed at operations such as:
1. Mechanical machining of propellants
2. Preparation of oxidizers
3. Charging mixes through screens to the mixer

It is felt this matter to be one worthy of more specific attention in safety regulations as it is understood that operational shielding differs among solid propellant manufacturers.

C. We have an R&D test area in which the following tests and studies are conducted:
1. Static firing of smaller motors in fully barricaded (including the overhead) cells.
2. Environmental testing (rough handling, altitude, salt spray, etc.) of motors and igniters.
3. Temperature cycling and conditioning of motors and igniters.

An exemption from Section 19 of the Manual is necessary in order to temperature cycle and condition propellant and igniters in the same cell. Numerous temperatures are required by various contracts and it is required that all components of units be cycled and conditioned under identical circumstances. It is felt that this cycling and conditioning is not storage per se, but a process, just as in an operating line, and as such should not be subjected to the storage compatibility tables. This is a matter that needs to be more clearly defined in our regulations. The provisions of neither Section 15 nor Section 28 of the Manual are suitable for such an area, and since these tests are essential to R&D work, a new concept of a test area is needed.

These are representative of the problems and conflicts we encountered in the application of the Manual to solid propellants operations. It is recognized and appreciated that the bulk of the Manual contains the excellent safety provisions--provisions which are wholeheartedly supported and exercised by us. However, our plant has been allowed to deviate from certain provisions of the Manual and our common sense approach has not sacrificed basic safety in any of our operations. This statement is supported by the fact that our plant has worked since 1953, 11,744,416 manhours without serious disabling injury or fatality. A review of our plant frequency and severity rate indicates we are lower than all other industries who have operations similar to ours. As an example:

Comparative Injury Rates

Industry	Frequency	Severity
McGregor Plant	2.27	39
Aircraft Mfg.	2.30	251
Propellant (Powder)	2.35	1265
Chemical	3.73	535
All Industries	6.84	795
Petroleum	7.69	827

Ways and means of improving our safety performance are constantly being sought. Therefore, we feel that due to the ever changing technology in the field of developing solid propellants, it is necessary that all planning, policies, and application or interpretation of regulations be based upon a constructive, reasonable, and judicious analysis of the actual need.

Practical ground rules governing solid propellant safety must be formulated, and of prime importance is the recognition and acceptance of the principle for the use of sound judgment rather than unyielding insistence upon meticulous compliance with a publication.

I sincerely hope this discussion has created some interest for all who are engaged in the manufacture of solid propellants to analyze and study the critical need to establish definite practical safety rules to be used in explosives operations in the solid propellant field.

Mr. Bishoff: I'll bet you all thought that Mr. Molloy was talking about an Ordnance installation. Actually, I believe that the case is this: during the war, Bluebonnet Ordnance Plant at McGregor, Texas, was a bomb-loading plant. I can vouch for this; I happened to be stationed there then. After the war, the plant was closed down and was turned over to the Air Force. Mr. Molloy was operating under an Air Force contract. I certainly appreciate, I think, the plug for the Ordnance Safety Manual, but I have no knowledge of all the trouble it has given Plant No. 66.

Mr. Molloy: Well, Mr. Bishoff, I wouldn't say that it has given us a lot of trouble. I'm just bringing up some problems that we've encountered that we feel other manufacturers have encountered. They have been discussed and their areas were not published by the Manual or covered by any other regulations. When it leaves it up to interpretation, there are many interpretations.

Mr. Endsley: You are speaking of an age-old problem that I'm sure most of us heard from coast-to-coast and from overseas. It isn't new or it isn't unique. Neither can any regulation or any document written today be applicable tomorrow. No one has intended this, I'm sure. As you can all witness by the discussion here, there are new things coming in each day that require changes. There are procedures for these changes, and that is all you have to do.

Mr. Jezek: I had a question, but Fred Bishoff answered it. I was wondering who was giving you all these waivers because we handle them, and I haven't seen one come across my desk.

Mr. Molloy: Actually, we think we have had very few waivers and only two or three exemptions that I know of. I say, we have been living with the Manual, and we are using it as our guiding principle. We are advocating, rather than a real tight literal interpretation of the Manual, where the area of new things have been coming up every day in our research and development effort, the common sense of the people available or a practical solution to use for the problem. Where the big problem lies is this: the people who originally discussed the problem and made the decision may no longer be there. Then, when someone else comes in, your practical solution isn't quite as practical to him.

Capt. Jenkins: From my own experience, I think that common sense is used many, many, times in judging these things. Sometimes people think it is too complicated, but I see it injected into the picture a lot. Maybe you don't hit everyone, but you have to have a standard guide; there can be deviations when based on common sense, good judgment, and the other factors like that.

Mr. Molloy: Well, one statement that I would like to make is that we are fortunate that we have had Mr. Shaw right at the plant with us and we can

make these decisions. He can help speed up the processes.

Capt. Jenkins: Just one more question.

Mr. Saine: I believe about four years ago, an awful lot of people spent an awful lot of time working up some revision to this Manual, bringing it up to date. I wonder whatever happened to those.

Mr. Molloy: I can't answer that question.

Capt. Jenkins: Mr. Queen, haven't you been sending him the revisions?

Mr. Queen: I'm not so sure that I understand the question. As far as revisions are concerned, we are constantly in the process of revising the Ordnance Safety Manual. We have eight changes to date, or at least the eighth one will be out in a matter of weeks. There will probably be a ninth one following closely on its heels. So, beyond that point, as far as the specific field that we are talking about, solid propellants is concerned, that is not so far along--at least in the composite range.

Mr. E. E. Katcher, BuOrd, Navy: This question of Safety Manuals has been one which, I think, plagued the people in solid propellants for the last ten years. The Manuals that exist do not adequately cover the areas such as Mr. Molloy brought up. New plants or new operations have always raised these questions as to what classification and what safety criteria should be used. The existing documentation just barely covers rudimentary guidelines. I think what we need and I'd recommend that we attempt to do this, is to combine Army, Navy, and the Air Force safety requirements into a single military standard Manual. We have done quite a bit of standardization in the last five to ten years in many areas. I think this is one which needs concentration of effort. The objective of this meeting, "Trends of Highly Explosive Propellants," is very timely. I think one of the things coming out of this meeting should be a real strong effort into bringing up-to-date the requirements and the needs of industry, and keeping them current. Somebody mentioned four years for changes. This is hardly adequate for a moving industry like this is. We need them at least--I'd say the maximum is once a year, if not every six months, to bring up the needs and questions and the accidents which occur which point out the need for changes. I don't believe that we have been doing as much as we could in this area.

Capt. Jenkins: I believe you mentioned earlier about the need for more expeditious delivery of incident reports. Were you the one who mentioned that to me?

Mr. Katcher: The objective is in having each organization that is working in the field, whether Government or private contracter, submit their results in real brief form, for each accident, its causes as determined at that point, and the corrective actions and recommendations that were necessary. This information could be sent to SPIA who normally sends out abstracts of information reaching them periodically; but at the end of the year, I would

recommend that a volume be prepared, preferably by SPIA or the Explosive Safety Board, and distributed to each and every organization working in the critical field. This volume could contain the results of all the accidents properly tabulated and correlated so that we could gain the benefit and save lives and property. This is something that has disturbed me for the past five or six years, and I'm glad to see that this meeting is aimed at that objective.

Capt. Jenkins: That subject was an item on the agenda of the Board some months ago; and as a result of that, we investigated, with the secretaries of the services, on how their Incident-Accident Reports were distributed. I think the Army does a very good job, the Navy and the Air Force have come more into line; but there is a procedure being put into effect to get this word out to you. In fact, the Accident-Summary Report that you people got today was an outgrowth of the discussions and meetings which we had regarding that. This Accident Report does not cover every single accident. The one that happened on New Year's Eve down here, which was discussed at the Seminar, is not listed because we are waiting for the investigating report. However, the reason for the summary report is that it goes to the service, and it goes to the represent tives who are working for the various services. If you see a certain particular incident in there which has a particular bearing on the kind of work that you are doing, then you can go through the proper channels to get more information on it. Some of the material is classified, but there is enough in there to whet your interest. We are putting that out, starting that old ball rolling to make sure the people who work on this business will get the information on other people who have had the problem.

Mr. Roylance: I'd like to get back to this problem on the Safety Manuals for a minute. We have been talking for two days now about these solid propellants getting closer and closer to high explosives. The present Manuals admittedly are based on high explosives, with smokeless powder also included. I think you will find that any major problem which comes up will be adequately covered in the Manuals if you follow the procedures for high explosives. This isn't going to hurt you too much. In fact, it will probably help. I think most of the things are in the minor category, like compatability, temperature conditioning, and this sort of thing, which can very easily be straightened out. I don't see any need for major revisions of the Manuals or a separate Manual, for that matter, for the solid propellant industry.

Capt. Jenkins: That is another thing which we have been thinking about quite a bit though, the possible need for a Safety Propellant Manual. But don't forget that we are very early in the game. Yes, Mr. Bishoff?

Mr. Bishoff: I'd like to say a few words on the same subject, and in a way, answer Mr. Molloy. The Ordnance Safety Manual was written to try to cover, in a general way, over 100 ordnance installations in Continental U. S. There are a certain few ordnance installations that are involved in a specific type of manufacturing operation, and we in the Army Ordnance Corps prefer to write a separate safety Manual which supplements the Ordnance Safety Manual, and beamed specifically at this type of operation. You may, or may not, realize

that we have a Manual on the safety requirements for the manufacture of nitroglycerin, another one for manufacture of small arms ammunition, and for some of the single and double base propellants. We are working now on a draft, a separate Manual for manufacture of composite type propellants. I'd like to make this offer to all assembled here; when we are ready with our initial draft, we would, if you are interested, be happy to send a copy to you to gain the benefit of your experience and comments. If you are interested, I'd appreciate it if you would give your name and address to Mr. Walter Queen of the Safety Branch, OCO, and when we are ready, we'll send our draft to you for comment.

Mr. Molloy: One last comment. As I say, I was given this topic based on some questions that were asked; and asking the various people of the solid propellant business what the problems were. We consider these general enough to discuss them today because I couldn't get up and say that the Manual is fine, we have no problems, just use it. We try to do that, but there were problem areas which should be discussed and brought up. Now, what Mr. Bishoff has said was the general consensus of the opinion of everybody I talked to about it. It would really aid if we had a supplement to the Manual which might cover some of the areas which are not covered at the present time.

Capt. Jenkins: Major R. C. Hegeman, of the Ordnance Ammunition Command at Joliet, has the next agenda item. Major Hegeman?

Major Hegeman:

SUBJECT: Predetermination of Explosive Classification of Research and Development Items Prior to Their Release as a Standard Item for Manufacture or Procurement.

OAC FUNCTION: Gentlemen...Our responsibility at the Ordnance Ammunition Command is the Procurement or Manufacture of Propellants and High Explosives for Industrial Production of Ammunition Items and their Supply to our Military Services.

OAC FACILITIES: OAC has the real-estate- the facilities, such as Works for the manufacture of propellants and explosives; Plants and Facilities for the production, loading, and assembling of the finished conventional ammunition. The explosives hazard classification for these conventional items was established prior to construction of the facilities.

BACKGROUND: Looking back towards by-gone days - the days of development of conventional ammunition - it is possible to see how in the leisurely development processes it would have been possible to study and test propellant formulations in such a manner that by the time a propellant came into production and use its proper explosive classification could have been well determined.

DEVELOPMENT: Its development would have progressed through the R&D phase, pilot phase, and into production of a pilot lot.

TESTING AND STANDARDIZATION: Following this, a firing schedule would have resulted in standardization. Along with all these steps would have grown a set of procedures, a set of fixed specifications-and, incidentally a determination of the explosives hazard classification or classifications would have evolved.

COMPARISON: While the determination of hazard classification cannot accurately be made on basis of evaluation by comparison with characteristics of known properties these factors, plus tests, should go a long way toward such a predetermination.

TRUE PICTURE: To arrive at a true picture, the method desired must of necessity establish a hazard classification for each individual item on the basis of:

a. What it does under certain conditions.
b. Chemical content (characteristics).
c. Total energy generated (content).
d. Rate of energy generated.
e. Impact sensitivity (drop-test - rifle bullet).
f. Propagation of detonation (shock wave).
g. Heat sensitivity.
h. Gas generation at ambient and storage conditions, etc.

PRESENT CONDITIONS: Under present conditions, almost none of the phases will have been fully completed at the time of initial production. Rounds and rockets for completion of R&D will be scheduled for production at the same time that qualifying rounds and rounds for initial production are manufactured. The pilot plant will be "telescoped" with the production facility. In other words, pilot developments are overlapped with production. Aspects of the specifications for the item are frequently dependent on the production capability which is established in this overlapping developmental production.

OUR PROBLEM: Unless we have a usable standard method for predetermining hazard classification for questionable materials it may be necessary for us to plan and construct our facilities based on the highest or class 9 hazard classification.

OUR NEED: What we need is a usable method for predetermining explosive hazard classification of high energy propellants in all stages of manufacture or production and storage. This should be done in the pre-production phase.

TO HELP US DETERMINE: Since our existing facilities were designed for production of conventional types of propellants, therefore, being armed with

a predetermined hazard classification it would be possible for us to determine:

First - If our existing facilities which involved large initial investments are suitable for the production of the new high energy items with regard to design, quantity-distance, general construction and location.

Second - If need be, whether or not our existing facilities would be suitable for modification without too great an investment, or

Third - If it would be more feasible economically to construct new facilities having the design criteria required for the various hazard classifications of the item to be produced - in every stage of its manufacture, production, and storage.

QUESTIONS AND NEEDED DEFINITIONS: The following are some questions and needed definitions which may assist us in arriving at a usable method of determining an explosives hazard classification:

a. What is a high energy propellant? What are some examples?

b. What hazard classifications are involved? (Class 2, Class 2A or Class 9?) What is the form of material? Its geometry? Its packing? Its processing stages?

c. How new is the propellant to be "predetermined?" What similar and comparable materials are pre-existent, and usable as a guide?

d. What basis other than that of historical similarity can be used in predetermining the classification? What test results are available?

e. What is the composition and the energy content? What is the shock sensitivity? The shelf life in storage?

SUMMARY: When answers to the above or similar questions are obtained as applicable to "high energy" propellants under consideration, a step in the right direction will have been taken toward deriving a hazard classification. Being armed with the explosives hazard classification, of the high energy item prior to release as a standard item, for every phase of manufacture or production and storage, we will be in a better position to plan either the utilization of our existing facilities or construction of new facilities without exposure to unnecessary incidents that may result in injuries or fatalities and costly damage to Government property.

Capt. Jenkins: In our discussion this morning, we got into the business of

"hazard". I hope we didn't get too much into your field, Major. If we did, you have my apologies.

Major Hegeman: Well, I think several of the speakers this morning have "stolen a lot of my stuff," so I'm going to give you a chance to pick up some of mine, here. My subject was to have been the "Pre-determination of Explosive Classification of R&D Items Prior to Their Release as a Standard Item for Manufacture or Procurement." I think we had a pretty good discussion this morning on what is being done by Picatinny and by other people. To come up with an answer to this question of just what is the hazard classification of these new, sometimes exotic, explosives or propellants--our particular interest at the Ordnance Ammunition Command is in the utilization of facilities. Depending on what classification is placed on these items, we have to make a decision as to whether we can go into an existing Government plant and manufacture these items. Now, whether these be Class 2 or Class 9, what I mean is, if they are Class 2 or Class 9, there is a lot of difference in what we can do in these plants, quantity distance-wise and in other ways. At present at Radford and Longhorn, we have tried to adapt existing plant facilities to the manufacturing of these new propellants. This has caused "growing pains" or whatever you want to call it. In the case of mobilization, where it might be decided to use more of the existing Government plants or works for this type work, before we spent a lot of money to modify one of our existing plants, we would certainly like to know whether this is going to be a Class 2 or Class 9 hazard. Therefore, at OAC we are very interested in the work that is being done to come up with these answers. This, basically, is our problem; it's everybody's problem--not only ours. We are particularly interested from a production standpoint on how much money it is going to cost us to convert facilities in case of an all-out effort. As I said to begin with, I don't think that I'll go through this whole presentation that I have here because everything has been pretty well covered. So, I think that I will leave you with just that problem, which is OAC's problem. We would like to get this hazard classification to aid us for future production.

Capt. Jenkins: Well, we were a little pressed for time on that subject this morning. We have a little extra time if any of you have any questions you would like to address to the Major or to Mr. Herman. Mr. Katcher?

Mr. Katcher: The problem of explosive classification of solid propellant rocket motors is another one of those items which has been pressing for many years--I'd say for at least 13 years. About 1946 or 1947 a certain rocket motor which was shipped in one direction as Class 2, another activity had an occasion to ship it back and they shipped it back as Class 9. At that point, it became evident that something needed to be done and people started working on it. The point I'd like to raise now is that we are now working on it. What is the target date for completion of the standards? We need them. About five years ago we had one contract for rocket motors and the shipment costs of Class 9 versus Class 2 on a single contract were resulting in $500,000 a year excess cost to the Government. The difference of the hazards were unknown because of arbitrarily establishing classifications without actual tests. So, can somebody tell us when we are going to have a

military standard for classifications that the Army, Navy and Air Force can use on a regular routine basis?

Capt. Jenkins: I'm going to go "way out on a limb a hundred miles." Bob, with your permission can I say about two months as a brief answer? You are from Washington, you know that we can't make decisions like that there. But we will be through with it in a couple of months That will, at least, satisfy some of your doubt.

Mr. Katcher: Thank you. I hope we will all concentrate on this and get this job done.

Mr. Jezek: In connection with this classification of a motor, I don't know whether the gentleman realized it or not; but that particular rocket that he is talking about, if it is the same one I think it is, has been reclassified for the past year or so, I think. This was the result of a test conducted at Dahlgren. We came to an agreement, if I'm wrong, I think that Bob Herman can correct me on that, that motor has been re-classified and I don't know where this $500,000 comes in because, as we all know, you can ship a Class A motor or a Class B motor for practically the same price. It all depends on your freight tables and a few other things. At one time, I was led to believe that if you shipped an item as a Class A item, it would cost you a lot more than a Class B, but the transportation people tell me that they have a code and various tables that they have to go by. It isn't only the Class A or the Class B that comes in, it is whether you ship it over a land-grant road and a few other things are involved. I think Mr. Joe Bee can probably help out a little on this, too. Don't let that $500,000 figure get out because if Congress finds out about it we are going to be in an awful mess.

Capt. Jenkins: I've heard about that particular rocket about a thousand times, I know. Mr. Bee, could you add something to that?

Mr. J. F. Bee, BuOrd, Navy: Well, I have conducted several tests down at the proving ground and we have established specifications for quite a few of the Navy rockets. We had a little bit of revolting information the last couple of weeks. We found out that some rockets that we had previously classified in one bracket, after they were in storage for about 5 years, their characteristics changed and you are in another classification bracket. So, it may be that your classification criteria might have to be made out of "rubber". This is a new problem that has just come up in this field, which tends to amplify or point out the difficulty in trying to arrive at a standard criteria because of the changing technology and the different changes in chemistry and the motors.

Capt. Jenkins: Captain Clark, of WADC?

Capt. Clark: Apparently, you all are saying that you will have your criteria out in the next month or two. Is there any indication that there will be a military standard also to follow that?

Capt. Jenkins: Bob, I believe that the ultimate plan is that would go out as a service guide and not a DOD directive.

Mr. Herman: It will be a service guide.

Mr. Haite: This document, whatever it happens to be, is it going to cover the number one item of Major Hegeman's topic here? That each pays the manufacturer?

Mr. Herman: No, the minimum criteria which we are developing is for finished items only. It will not get into the various stages of manufacture.

Mr. Haite: Is anything being done in the manufacturing area?

Mr. Herman: Not by the group of which I am chairman.

Capt. Jenkins: Mr. Bee?

Mr. Bee: I would like to point out one other flaw in this anxiety for a hazard classification standardization because you already have your requirements established by ICC. They specify special tests that you should perform. If you are willing to buy the motors and put up the money to do the test, you could establish your hazard classification.

Capt. Jenkins: Are you ready to supplement what Mr. Bee said, Mr. Herman?

Mr. Herman: I'd like to ask the panel a question, if I may, in connection with Mr. Haite's question.

Capt. Jenkins: Okay.

Mr. Herman: It was my understanding awhile back that, for economy's sake, and the constant change in manufacture of these various propellants, the Class 9 distances were to be used to establish the quantity-distance separations in manufacturing plants in the future. I wonder if the panel would care to comment on that.

Mr. Roylance: This is true as far as the Navy is concerned. This is on all manufacturing processes through curing. After that, after the thing is cured and really a completed grain, we then determine the classification of the grain as such. But, we always figure that sooner or later you are going to get the worst case and you might as well lay out your plant for the worst case which would be high explosives, Class 9.

Mr. Endsley: We follow along somewhat the same lines with the exception that in certain phases of operation, there has been given some latitude for classification. AMC currently has some policies out on this and Ogden Air Material Area may have some pertinent information on guidelines for the methods of production. They don't follow along the line and there is some latitude from point of intake to point of finished item, but the finished item, as Mr. Roylance pointed out, would be coming under the minimum classification tests.

Mr. Bishoff: I'd just like to relate how we work things in the Army Ordnance Corps. If you are working on an Army Ordnance Corps contract to manufacture

a definite propellant grain having a definite formulation, your processes are somewhat standardized. The Ordnance Corps will classify for each phase of operation, what the explosive hazard is. If you are looking for an overall classification for phases of manufacture of, say, composite propellants, we just can't give it to you. You are always changing your formulations, your percentages, and ingredients. So, about the best we can do is generalize, and when you do have a contract to manufacture something to a definite formula, then we can come across with the proper explosive hazard classification during each phase of operation.

Capt. Jenkins: Thank you, Mr. Bishoff. Well, with the hearing that we had this morning and the hearing that we had this afternoon, there are a lot of problems in it, but, I think that we have sufficiently covered it. Thank you, Major Hegeman. Mr. Shell Martin?

Mr. Martin: I would like to raise a question here, not being in the explosive field myself, more in the facility type of thing. I note here in this topic we are discussing that the second part of it has to do with final storage. Then we always talk that we are gradually approaching practically a TNT type of thing, or mass detonating or something. Now, to get back to what has been said here, then how important it is--looking ahead here--to attempt to classify on final storage basis, something that we have got now building very costly fixed facilities. If it looks like we are going to get into something that is Class 9, we will go to Class 9 to start with. I just raised this as a question since it appears that we are going to deal mainly in various size rocket motors, and may end up with this situation in a few years.

Mr. Jezek: I think that has been taken into consideration. We won't lay out an Ordnance installation or a plant based on some lesser distance than Class 9 or 10. All of our storage depots are correctly laid out on the assumption that you will put the maximum quantity of high explosives in that particular magazine. Mr. Endsley tells me that so does the Air Force, and the Navy too. They are all laid out on that assumption that sooner or later you will put bulk HE into that particular structure for storage purposes.

Mr. Katcher: I'd like to ask Mr. Bee a question which went by pretty quickly a little while ago, concerning the change of classification of rocket motors in storage. I'd like, after I bring up a couple more points, to have him try to clear that one up for us. Just what motors were tested and how did they change? From 2 to 9 or 9 to 2 or vice-versa? With respect to the items that Mr. Bee mentioned ICC tests, I think that perhaps it would be beneficial if the test program which the Explosives Safety Board comes up with could be proposed to ICC and accepted by them as being a single set of test criteria that we use within the civilian and military operations, so that we are working along the same basis. I think this would be very desirable. The third item which I would like to mention is the item of costs, of striking from the records this item. I will go along with that, provided that when the revised classification standards are brought out, they are sufficiently defined and correlated with costs and figures for various types of shipments, so that this problem will be clarified for everybody concerned. As it is, the figure of

$500,000 is an actual cost figure paid by the Government by information obtained by our Navy people out in Bar Azusa who had charge of shipments of these units. They are the ones who recommended that we put pressure on as far as we could, about getting the tests completed for this specific unit, which was the 15 KS 1000, in order that we would know, by test, what the actual classification of the unit was and whether we are paying the proper figure or not. On that basis, we pursued and pressed the issue, got the test completed, and it was classified as Class 2. The result of this was that we did save ourselves considerable money.

Capt. Jenkins: Did you want to take this up privately with Mr. Bee over in the Bureau of Ordnance?

Mr. Katcher: Well, if it is all right, or doesn't take too long, I would like to ask Mr. Bee to clarify the item of changing classifications on the ICC tests.

Mr. Bee: Approximately 3 years ago we ran some preliminary tests on double base rocket motors and the Navy derived a classification of Class B. These motors have been in storage now, some of them, for approximately 4 or 5 years. Recent tests in May indicated that the propellant has undergone a change and is getting hotter. It doesn't react quite as calmly as it reacted before, to similar tests as far as the ICC has laid down certain tests to do. It is the booster motor. Different services interpret different methods for performing these tests and consequently, there were different classifications for the same motor in different services. The object of the Board was to come out with a uniform test procedure for all these services. This is what we are attempting to do, but this in no way excuses anyone from regulations set up by the ICC. The object of the Board is to come up with a uniform method of classification.

Mr. Katcher: And there are members visiting the Board who know the regulations of the ICC and this has been channeled to them informally, the procedures and criteria established by the Working Group.

Capt. Jenkins: We are very much aware of these problems you brought up and all I can say, Mr. Katcher, is that "I think so, too." When we can get it done - tying in of Service classifications with ICC etc. - I don't know. We are doing what we can of it. Mr. Haite?

Mr. Haite: I thought most of the people here were familiar with this, but from the conversation, evidentally they are not. It is a simple matter. According to the ICC, the Military Department sets the shipping classifications. It is not up to the ICC to tell the military what classification it is.

Mr. Katcher: This is on military explosives proved by the Chief of Ordnance of the Department of the Army, Chief Bureau of Ordnance, Department of the Navy or Air Material Command, Wright Patterson Air Force Base in Dayton, Ohio. These are because of security classification and the ICC people are not cleared.

Capt. Jenkins: There is a law up right now, that one of our very prominent senators has drafted, and this law came over to the Board just recently--the normal procedure is that we do not interfere with the standards and the criteria set by the ICC except in times of emergency or certain conditions like that, when we will and the service classifications and the shipping criteria etc. will precede ICC. That is the thing that is going back and forth right now. We don't normally get into the picture and tell the ICC how to do it. Mr. Herman?

Mr. Herman: I would like to clarify two different points. I think the first is Mr. Katcher's. The ICC has suggested several times that they would be much better off if we had a separate set of regulations for military explosives and for civilian explosives. However, they have also indicated that they have no personnel to do this. The if Military Departments are willing to draw up these seperate regulations, well and good. As I mentioned this morning in hazard classification the group has decided that for military explosives, we will subject them to a more stringent test than is part of the ICC. You could take a Number 8 blasting cap and put it in an item and test it twice. One time it detonates and the second time, it doesn't. Then it doesn't have to be a Class A explosive according to the ICC. We would never buy this for a military explosive, and you would never get civilian industry to buy this test that we set up for military explosives. To answer Mr. Haite's question, I think several people in the room here will remember the incident where we were running some tests on a propellant, and one of the Bureau of Explosives representatives was present. When we got ready to run them, they said that they wouldn't buy those tests, and would not accept our classification. We had overprinted it and they would never find that condition in existence. They said that if we didn't change it, they wouldn't buy our classification, so we don't tell them, in all cases, what the classification is.

Capt. Jenkins: Just a moment--Mr. Smith was going to present that other topic. Mr. Haite?

Mr. Haite: I was speaking of Supplement 7 to the ICC tariff regulations. It is a new supplement which came out not too long ago.

Mr. Jezek: I think that if you will read that supplement, it will tell you that all the military can do is approve new items of explosives or ammunition for shipment. As you all know, especially you people in the commercial game, when you make a new item, you have to submit that item to the ICC for classification and nomenclature. However, more than once, we have sent items up to Harry Campbell and he would say, "Well, what do you want to call it?" "Is it all right with you?" "If that is the way you want to do it, okay." So, as a result of this, we held a meeting in Washington, and we had the regulations changed so that you people would not have to submit your samples to ICC. All you have to do, if you are in the Navy, is ship them to Roylance's office, I think; but anyway, I stand corrected, if you have a new item, there is an Ordnance Corps order for the benefit of you ordnance people, that tells you how to go about getting some new items approved for shipment. Now, I may be wrong, Mr. Haite, but I would check that regulation again.

Major Hegeman: Smith, do you want to say anything? I might have sounded off a little prematurely. I haven't heard anything from you.

Mr. Smith: Well, I'm reminded of what Henry Marsh said the other day that 41 years ago, we started out, and inasmuch as it was 41 years ago, I don't think that I have much to say now. I've just been listening, but there is one thing I'd like to say. We have been talking about storage. Storage ties right in with what Major Hegeman said. It is all one subject, but we are particularly interested in the questions brought up and I think that Mr. Bishoff answered it for us. We do not want, the next time we have to reactivate a line, or modify a line, to come up with what we did at Sunflower when we modified a single-base line to triple-base. We got all the regulations we knew about, improved and everything, and then when the manufacturer found out that we had violated every rule in the book, we had to get a waiver. Now, we don't want to do that; that is what we are asking you today. Next time we modify a line, be sure we have the right criteria so it will not cost us too much money. Thank you.

Capt. Jenkins: Thank you, Major, and Mr. Smith. Mr. Haite has kindly consented to "come to the rescue" here on this next item we have regarding the design of motor cases, casting equipment, etc. Mr. Haite?

Mr. Haite: "The Design of Motor Cases and Casting Equipment to Avoid Threads." The same method has been followed, in general, up to the present time, by those installations making motors for the various Services. In the past, there have been a number of incidents that were laid directly to the fact that we did have thread in our casting fixtures and in our process lines. In general, and very simply, we have wherever possible, replaced all connections with the "Marmon" type -- not necessarily a "Marmon" clamp, there are several clamps on the market, but essentially that type of arrangement. You have the male and female flange and all around the flange, you have an O-ring. Then you have a clamp, or band, that is around the flange holding it together. This eliminates the threaded section and also facilitates disassembly and assembly. It makes it much more readily cleaned. The motor cases I believe-- for those unfamiliar with the motors that are being designed at the present time -- several designs in the mill are going to the V-slot type, even. Others, to hold the fixtures on, have several individual splines on the exterior so that you don't have to screw the nozzle closure onto the rocket motor case. In the past, there have been other ways of fixing these closures with snap rings or ring seals. This was particularly true back in the days of the Navy 2.75". That was fitted in such a manner. We are doing the same thing where we can on casting cases. Since most of our work is done with casting from a pressure vessel where the propellant is forced out of the cans into the rocket motor under gas or air pressure, the lid of the can is essentially a small piston with a massive O-ring, you might call it, around the perimeter of the lid, and this lid is held in place with a large Marmon clamp. I believe this covers the point sufficiently; I did want to bring this to the attention of all the people gathered here. If there are any comments that I have missed, or any questions -- fine.

Mr. Mack: Do you normally run an O-ring compression, and to what extent do

you set up a specification for O-ring use in such a manner with a Marmon clamp?

Mr. Haite: We use the regular O-ring standards on this.

Mr. Mack: In other words, 5 to 18 percent or something on this order?

Mr. Haite: Yes.

Mr. Mack: This is one of the particular problems you get into in the use of O-rings. It can happen that sometimes you have a failure due to O-ring failure, if adequate compression data is not available on a particular O-ring before it is put into service.

Mr. Haite: Well now, in the case of our processing, you will have to understand that we are operating in an awfully low pressure range.

Mr. Mack: True.

Mr. Haite: We have found that, in the recommended use of O-rings by the standard book, the recommended uses have never resulted in a failure as far as we are concerned.

Mr. Mack: Well we, of course, operate in the cast double-base system. Sometimes we use higher pressures - liquids, etc. - than you folks normally do. We have had some cases where inadequate inspection of O-rings has resulted in failure, so I would like to point up this for people who like to go to Marmon clamps and O-rings, you have to check yourself as you go along.

Mr. Haite: In some of our larger operations we do not use the O-ring in compression, i.e., between two mating flanges where the flanges are parallel. We use it on the longitudinal axis.

Mr. Mack: One other mention I might make that, to design for the elimination of threads is desirable; sometimes it is not always possible. We attempt to do essentially the same thing using snap-ring or half clamps for mating surfaces that you can clean. The primary problem is one of inspection and cleaning of the groove prior to putting on a clamp - prior to putting pressure onto the system for pulling the cord, or something of that nature. It is also another point for double-checking oneself, at least. In some cases, on higher performance cases, it is necessary to go through extremely elegant type of connecting fittings, and the weight, even in the Marmon B band, cannot be used.

Mr. Weintraub: I think that the last remark is just what I was going to say. Right now the motor as used for the space programs, and also for ICBM's and IRBM's, sort of obviates the use of threads altogether because of the fact that you are trying to get the propellant densities to lows of .89 to .90 or .91; I don't think we will ever get there. This obviates the use of threads, so I think that we are going in the right direction anyway.

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Capt. Jenkins: Mr. Guzzo.

Mr. A. T. Guzzo, Thiokol Chemical Corp.: Bill mentioned a few points and one was in connection with valves. There are various types of flex-valves used to control propellant flow, several commercial varieties. Generally, we stay away from all valves with metal parts. Plug valves are sometimes used but generally they are a home-made variety. We use a lot of fire hose with special Marmon-type connections and I guess that pretty well covers that point.

Capt. Jenkins: Thank you very much, Mr. Haite, for "carrying the ball" here. I'll let Col. Couch say what he has to say without any preliminary remarks.

Lt. Col. Gerald Couch, USAF, ASESB: My objective on this subject was only to get you to talk, so maybe that objective was already achieved in some of the comments. All of our discussion up to now, primarily, has been concerned with the hazard involved in explosives during manufacture. We haven't gotten much into the hazards involved in the end item, and we really didn't intend to in this seminar. Certainly there are hazards involved in the end item but those hazards are not necessarily explosive hazards. In fact, many people have made the remark that we may prefer to get involved in an explosion incident with some of these propulsive devices, rather than have them propel themselves across the country. This certainly is a matter of concern with safety people as well as operational people and R&D people. Many, well, I won't say many, but there have been some means devised in the past on some items for preventing an item from propelling in the event it gets in a fire or gets ignited by some other means. Some of these have been by means of movable exhaust nozzles or some means of diverting the exhaust at right angles to the longitudinal axis of the motor; another means is by developing hot spots in the case so that the case will rupture rather than propel; some means of opening the forward end of the booster so that the exhaust comes out both ends and therefore counterbalances. I think Captain, that we should utilize the rest of the time for any discussions between themselves that they might have.

Capt. Jenkins: We could just throw any ideas into the pot then possibly, on how they could prevent the weapon from going out the end of the building. Mr. Graham, do you have any ideas?

Mr. Graham: I'd like to ask the Colonel what, if anything, they are using in the Air Force for non-propulsive devices on any of their missile systems?

Col. Couch: I'm not really prepared to answer that question. I know of one that is used in one rocket where the forward end has a plug that can be removed during handling processes. Another one is by means of attachment of an item through the exhaust nozzle which will cause the exhaust to be diverted at right angles.

Mr. Graham: Do you remember the names of those missiles Col.?

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Col. Couch: The MB-1 rocket is one rocket that we have that has - this will be Confidential - the Sidewinder which is a Navy missile has the device and that is also Confidential.

Mr. Endsley: Likewise, this is Confidential - you have to be a little careful of these stress neutralizers - we had occasion with one of them to cause a case rupture and this can be a little more hazardous than if you just let it burn.

Capt. Jenkins: This is something rather than a solution to go into an idea.

Col. Couch: Our objective was to get you people thinking about it and encourage development of some ideas other than what have already been used.

Mr. Graham: That was one of the reasons behind my question because we do have it on the LaCrosse missile and I was looking for some other bright ideas on it from the other Services, frankly.

Mr. Weintraub: I think it really depends on the missile system. Now everything I say, I think, will be Confidential, but as far as the Minuteman is concerned, it depends on whether the thing is operational or not. Now if you have an operational missile and its during a crisis, let us say, you don't care whether or not the thing does become propulsive. You just take the calculated risk. However, I don't think you'd want to get into the motor design and try to put in stress reversers or some way of stopping the thrust other than perhaps opening up the case and this is one of the things we are looking into right now. The case is very thin and in the event that you were involved in an accident, the pressure would be so great that I am sure that the particular motor that was involved would rupture. However, as you have many other stages, in other words there are two other stages, this means that there is a possibility of one of the other stages becoming propulsive, which of course would not do. Now, one of the things we are looking into is just using a can opener and this is rather simple because the only thing that would happen as if the thing would become propulsive, you would just jab the case and that would be the end of it. The case would open right up. These cases are very thin, as you know. I'm talking about this being set up. In other words, in the particular transporter at the time, so that in the event it would try to take off and move forward, it would impale itself on the particular spike and this would open the case up and there is no problem at all there.

Capt. Jenkins: That is good. That is the type of material we wanted to bring out. Do you have a question Mr. Weintraub?

Mr. Weintraub: The question has been asked, has there been any thought given to primacord. Well, we do have complex destruct systems on each one of the stages. (Everything I say is classified.) This is because of the Minuteman, it was at one time Secret, but we have gotten it down to where, except for

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certain things, it is Confidential.) We do have complex destruct systems on each stage. This will either be primacord or linear-shaped charge, however, the thought of having the person in the transporter having the capability of turning a key, shall we say, and opening up these engines is still a thing that has been under study. However, we feel that the man should not be able to destruct the cases and this is one of the assumptions on which we are working now and as I say, one of the simplest things will be to just have it impale itself. I say you have to set up the ground rules because as far as during a major conflict etc., you wouldn't care if the thing became propulsive or not, you just take the calculated risk.

Capt. Jenkins: We're thinking chiefly in terms of storage, transportation, and also this is destructive; throwing something into the pot on the advisability of design; putting certain features into the design to prevent them from taking off.

Mr. Weintraub: I think you have to realize that the missile concept here is a little different. Now when you say "storage," storage to me means something else. It means to me that we stick it in a hole and we don't care what happens to it in the hole, it can detonate, it can go up, we don't care at all.

Mr. Burton: We have a whole committee there on the subject of the safe storage and handling of these large flyable missiles and our feeling is this, as long as it is within the plant, after all we are in the explosives business, and what happens there can be considered very unfortunate, but nevertheless, it is not in the same realm of "should we let one of these large weight motors get airborne, get out of our property and land, say in San Francisco," or something like this. This, to us, could do the whole missile program tremendous damage and so for this reason, we are willing to take almost any extremes to prevent this happening. The approach that we are most interested in at the moment is the design item and this has to do with plugging the ports, we prefer to do what this gentleman on the end here said (Mr. Endaisy) was real disastrous, it was the stress neutralizer I think you said that caused the chamber to burst. We want this, we much prefer this to happen within our property at least rather than have the thing take off because, well, Aerojet and I think the whole missile program could get a terrible name out of this thing if we were dropping a lot of motors down into the residential section, hospitals, schools, etc. So we are much in favor of the plugging all ports concept of the thing and making it burst, absolutely. We much prefer to risk an explosion than to have it become airborne.

Capt. Jenkins: Keep it in your own back yard rather than San Francisco.

Capt. Clark: I'm a technician on Bomarc. Right now we are using a so-called neutralizer for the motor by itself, on the overall missile system they are looking into also, neutralizers or combination of the partial reversal of thrust to get in there at zero. In the overall missile planning, it is

either tied down or neutralized at all points and we are having quite a bit of discussion among ourselves as to whether it is good to let it set there and burn for thirty seconds or to let it blow up. We are all at about the same stages of development. If we are on the highway, it is pretty hard to say whether it is better to let it blow up or burn.

Mr. J. F. R. Floyd, Applied Physics Lab., Johns Hopkins Univ.: In the Terrier program, we have been using removable igniters or non-propulsive motors for some time. In my talk, I think you'll see a good reason why we do. Essentially, during the shipment of motors we have the igniter designed so it will come out if inadvertent ignition should take place. When the unit is received at a depot and the motor is assembled into a missile, and checked out, we make the unit propulsive and attach the whole assembly to a vent pipe so that the gases will go out of the building in case of inadvertent ignition. When we put them in the magazine, however, we put the main booster rocket in a non-propulsive condition so that inadvertent ignition will not cause it to try to take out through the walls of the magazine.

Capt. Jenkins: This was a subject which we didn't think was going to be covered in the discussions, but we threw it in to get you thinking about it, it is something to keep in mind. Mr. Buckles.

LtCdr Buckles: Thanks, sir. We have had some experience down here with firings of "cast-in-place" large grains and these have malfunctioned. but I think it is of interest to note that in every instance there has been a case rupture of variable degree of severity which has released the propellant from the interior and it has burned. Now, I will not say that this will happen with an extruded motor within some sort of case or other, but we have found with cast-in-place large grains that this does take place and this is very desirable because we can control it.

Mr. Katcher: I think it might be desirable to consider placing in the requirements for explosives safety, the need for each rocket motor design to consider some method of making the unit non-propulsive. I don't believe today that there is such although certain areas of DOD, we in the Navy, in BuOrd have a general specification for design that we consider each new development, consider the requirements, we attempt to buy most cases by making the unit non-propulsive by venting from the front end if the design allows it where the igniter goes in. The areas are equal from the front end as well as the nozzle, but when one considers the problems of larger motors that we're making and we're getting into, and the hazards of inplant handling, shipment and storage, this problem appears to be taking on a more important aspect. On board ship, when we had small motors, 2" and 5" in size and small warheads, the problem on non-propulsivity perhaps didn't have as much importance as it does today when you have a missile (this is classified) such as Sparrow or larger sizes that have a significant warhead where the warhead could be stored in ready storage in a completely assembled missile, the requirements for having a thrust neutralizer back on the nozzle would be

mandatory and they are today and we are going about putting those in. The point I'd like to make is essentially, from what I've seen in designs that still appear to be coming out, many of them are not providing for non-propulsive features and if so, we could do the entire country, including the public, severe injury in the event that catastrophes can happen by freight cars turning over, or whatever it might be, and this will really upset things. I think we have a big job to do in this area.

Capt. Jenkins: That is within the prerogative of the Services in setting specs. Are you doing that in the Navy, do you know?

Mr. Katcher: Yes sir. In our specifications in the Navy today we are putting in these requirements.

Mr. Graham: Capt. Jenkins, some time ago people were talking about these ICC regulations and I would like to point out that one phase of that, I have forgotten the exact wording, but rockets, missiles, etc. when being shipped will have the igniter removed or otherwise be made safe. That was one of the things several years ago that got us into the thrust neutralizer business because of the fact that in some cases the design indicated that the igniter should be in it but we didn't want it in it and if the design specifically called for it in, then we would want the thrust neutralizer in it. That is just one thing and in answer to this other man's question, we, two years ago at least, had a requirement on all our missile systems that they have thrust neutralizers and as of the past week, we just completed another survey to find out how far each of our missile systems were along in doing just exactly that.

Mr. Mack: We might mention that each rocket, each system, is its own entity and as far as thrust neutralization is concerned, I think that the rocket designers and chamber people designers can come up with a thrust neutralizer system. Each one is a special case in itself. If we are going back into thick shells in some of the older units, why we have to go with forward venting and arm-safeing as far as igniters are concerned and blowout patches. We get into high performance systems and I'll stay off the classified areas in discussing them, they can be designed to a maximum pressure limitation and some of them have been tried. We can put in numbers of different types of thrust neutralizers. Each overall missile system requires its own and I don't think that we can come up with a single one gimmick that is going to suit everybody. We will be glad to take on this job of designing one for any one of them.

Mr. Weintraub: That last statement reminds me of the person who says he is for motherhood and against sin. Coming back to the engines we have, I imagine that you realize that a thrust reversal on the first stage of, for example, say a Minuteman missile which has almost 40,000 pounds of propellant is quite a thrust neutralizer. I think the way we are getting around this in the assembly and test area at the Cape is to have a quasi-test stand and tie the engine down while you are working on it. If the thing should ignite, it just

ignites and that's all, period. You just let the darn thing burn and what you do is open up your thrust systems, etc., with your overhead sprinklers, etc., and attempt to keep it minimized or under control, that's all. But you have the thing tied down so it is non-propulsive and can't go anyplace while it is being worked on in the test stand.

Mr. Jezek: Design that system for trucks and you have got it made. What keeps people worried about it is if you have one of these things on a truck and it takes off.

Mr. Weintraub: Right. In the truck we have, what we are trying to do is to have this impale itself, in other words, if it should attempt to move, it just impales itself on a spike and this is probably the simplest way, in other words, a can opener.

LtCdr W. L. Zimmerman, DASA: My comments should be considered classified. A number of the comments this afternoon have dealt with the problem of getting larger and larger rocket motors. One of the things we have concerned ourselves with here in recent months is the fact that a greater number of smaller and smaller missiles and missile systems are coming in to being. These will necessarily be placed near metropolitan areas and will have atomic warheads on them, but we are quite concerned not so much with the fact that the missile, per se, would enter someone's yard as the fact that it would be carrying an atomic warhead, and we may be able to accept, as we have done very recently, the impacting of a dud missile in someone's yard, but I doubt seriously if we will ever be able to accept an atomic warhead, even though it is to be essentially a one point detonation. That, I don't think, we'll ever be able to accept anywhere in any community. Therefore, not only transportation should be concerned so far as thrust venting or making these things non-propulsive, but I think that aircraft storage where a small type missile might be attached to the wing of an aircraft and it's left on a hardstand in readiness should be considered to be completely non-propulsive until something is done as a physical act to that particular rocket motor before the thing is intended to be flown as a strike. This should be given very early consideration; otherwise, we may find ourselves in a position of having perfectly good weapon systems, but they have no readiness simply because we cannot make warheads of the desirable type with the propulsive systems that might come from high energy solid propellants.

Capt. Jenkins: You're right, and that is why we brought this up.

Mr. Haite: I have the solution to your problem, the only thing is, it will be up to you to implement it and that is, anytime that you ship rockets, ship two at a time and tie them together nozzle to nozzle. If one becomes ignited, the other one does and they are not going anyplace.

Capt. Jenkins: Thank you. It is surprising how you can have such difficulty sometimes in thinking, and then come up with such simple things. Well, anything else? We have had enough "airing" on that, Colonel, and thank you very much for coming into it. Mr. Floyd, will you make your presentation.

Mr. Floyd: "Shipboard Weapons and Ammunition Safety - Damage Control Aspects." With the commissioning of the guided missile cruisers BOSTON and CANBERRA, the Navy introduced into the fleet, ships having missile magazines each of which contain 72,000 pounds of propellant in the same space with about 7,000 lbs. of high explosive. Furthermore, the length of the Terrier missiles is great enough to require that the magazines extend well above the waterline and any armor protection and into the topside areas, which are more vulnerable to enemy action. To point up the significance of the hazards of this new type of magazine, it is worth noting that the two missile magazines on the guided missile cruisers BOSTON and CANBERRA are 60 feet apart and surrounded by crew's quarters and contain enough solid rocket propellant to require a building spacing for safety of 900 feet, if they were stowage magazines located at a rocket development plant. Furthermore, the same safety requirements would dictate that each of these magazines be located 3600 feet from the nearest inhabited building.

In addition to the existence of large quantities of propellant in a single magazine, the safety problem is aggravated by the need for stowing missile electronics in the same magazine. To meet the requirements for readiness of ammunition in defense of the ship, it is necessary to stow assembled missiles and warm up the electronics of the missile while it is still in the magazine. The firing circuits for the sustainer rockets are only separated from active missile circuits by the presence of one safety switch. Furthermore, the existence of active missile electronics in the magazine caused launching and handling system designers to install in the magazine, the electrical machinery and control panels associated with the transfer of the missiles to the launcher.

These magazine systems make the possible sources of inadvertent ignition of the missile rockets include faulty missile warm-up and firing circuits, human failures while handling or working around ammunition having exposed electrical contacts, fires within the magazines from other electrical and hydraulic machinery, electro-magnetic radiation, and the possible effect of enemy action which could lead to fragment penetration of the magazine from near-miss bomb attack or from rocket strafing. The exposed topside of the new missile magazine makes it vulnerable to this type of attack since the deckhouse protection may be less than the equivalent of 1" of steel. For purposes of development testing, it was agreed with the Navy that the fragment size which we could anticipate penetrating the ship's magazine could best be simulated by firing 20mm armor piercing or tracer ammunition into the missile rocket.

There are many Naval officers who adopt the attitude in connection with these missile magazines that "war is hell" and there is little that can be done to provide safety and damage control in the magazine except to isolate the individual missiles from each other with a minimum of weight penalty to the installation, and depend on a sprinkling system and CO_2 system to handle non-missile fires. However, others were interested in the degree of hazard involved and in the development of possible means for damage control. The Applied Physics Laboratory outlined a series of tests to the Navy which would

assess the hazard of this new ammunition in the magazine and permit an early demonstration of the value of damage control methods which might be applied. The experimental phase of this work was undertaken at the Naval Proving Ground in Dahlgren. From these tests, it was shown that by the introduction of a gas deflector in each missile, it was possible to avoid chain ignition of adjacent units in case of inadvertent ignition of the second stage rocket of the Terrier missile. However, chain ignition could not be avoided in the event of inadvertent ignition of the booster rocket. This was true even though the magazines were provided with automatic opening vents, which would keep the pressures developed within the magazine from exceeding the structural strength of the magazine walls.

This Laboratory then undertook to develop a detection and damage control system which would automatically detect the initiation of burning of one of the Terrier booster rockets and confine it such that chain ignition would not take place. This development was to take advantage of the previously designed non-propulsive igniter system which would automatically vent the rocket chamber through an area in the head end of the rocket equivalent to the nozzle throat. Evaluation tests of the non-propulsive device had shown that the rocket was not made completely non-propulsive by such a ventable igniter, since a net thrust of 13,000 pounds was developed by a rocket whose normal thrust was 60,000 pounds. However, the chamber pressure during burning was markedly reduced, and the burning was characterized by intermittent chuffs, which would permit more time for damage control.

Because we were dealing with a Navy weapon, it was logical to assume that a satisfactory quench or damage control medium would be salt water from the ship's fire main system or fresh water from a storage supply. Early tests showed that satisfactory quench of the burning booster rocket could be accomplished with as little as six gallons of water applied by a 2700 psi air charging system. Other tests demonstrated that by proper timing of the event, it was possible to quench the igniter and initial burning surface of the rocket with only ten pounds of water applied after inadvertent electrical ignition of the rocket. Later tests using water from a simulated 70 psi ship's fire main accomplished quench with 90 gallons of water after inadvertent electrical ignition, and quench with 360 gallons of water after gunfire initiation of the motor. However, there has been one occasion when magazine damage control after inadvertent rocket ignition by 20mm ammunition required the use of 1,350 gallons of water.

While the early tests for feasibility of handling the hazard with water injection into the motor assumed that the system could be activated within 1/4 to 1/2 second after ignition, the success of these tests demonstrated that a detection system capable of meeting these times should be developed. The physical characteristics of the burning which might be employed to serve as a basis for detection include the generation of heat, pressure, and radiation in the visible and infra-red range. Gunfire ignition tests demonstrated the desirability of a rapid detection means because, once the heat

of burning had fired the rocket igniter, it was generally found that the chamber failed, disgorging propellant into the magazine. Any weighing of the various types of detection had to include their freedom from inadvertent detection and also freedom from chain detection, which would deplete the quench medium or reduce its pressure and effectiveness.

The detector development work accomplished to date has shown that reliable detection can be realized with pressure detectors acting either on the shock wave associated with ignition and failure of the nozzle closure, or on pressure developed after onset of burning. One form of detection uses this pressure wave to act on a diaphragm which displaces and closes the switch in a water nozzle release circuit. It is also possible to detect rapidly with an infrared system, and we believe that this system can be designed to be free from the difficulty of chain detection and inadvertent operation during extended periods at sea.

In tests thus far with a water injection quench system applied to Terrier missile booster rockets, a level of success of 80% has been achieved with the complete detection and water injection system coping with the hazard of inadvertent electrical ignition. In other tests involving the ignition of rockets by 20mm ammunition, a quench or damage control success level of 35% has been achieved. Further tests are planned, with this latter hazard condition, to determine whether the advantages of more rapid detection by infrared means, or faster penetration of the water under the force of high pressure air will be required.

In April of this year, a magazine water quench system based on this development work was installed and put in service on the USS CANBERRA. The water nozzles beneath each missile in the magazine are backed up by a single fresh water accumulator charged to 250 psi. The size of the accumulator was selected to supply water to the ignited motor until such time as an additional ship's fire pump could be put on the line to provide a flow of 180 gallons per minute.

It may also be of interest to note that the test successes with this water quench system have led two solid rocket developers to employ the same system of water quench to determine the characteristics of the grain after partial burning. This has made the water quench system an important development tool for the rocket industry.

Capt. Jenkins: Of course, it goes without saying, that is the reason why the Navy is so interested in putting out the fire after it starts on shipboard. Any questions? Thank you very much Mr. Floyd for your presentation. Now, there were a couple of questions here which I left unanswered. Dr. Schaefer, is there anything that you feel you want to ask here before we terminate this session? Is there anything that wasn't answered to your satisfaction, or is there anything that you wish to discuss?

Dr. Schaefer: Well, I was just interested primarily in getting available information on the small laboratory mixer types. I gather, however, from talking to some of the people here, that there isn't any one particular

design that is going to meet all situations. It is just a matter of looking around and seeing what the various mixer suppliers have that might fit the particular circumstance that you are interested in.

Capt. Jenkins: Did you talk to some of the Allegany Ballistics people?

Dr. Schaefer: No, I haven't talked to them yet. I have gotten information from Rohm and Haas.

Capt. Jenkins: Allegany Ballistics, if there is someone here who can give answers.. Not to discuss it now, but discuss it later to help out Dr. Schaefer. They use those things a lot up there.

Dr. Schaefer: Thank you.

Capt. Jenkins: Are there any other questions or important points that should be brought up here?

Dr. Knapp: In some of the military installations that will be used for some of the intercontinental ballistic missiles or other missiles, you have a situation in which you can take almost anything that happens to the missile because it is buried in the ground. I take it that even something fairly close wouldn't be "all wrought up." Now, that is a pretty obvious thing, it seems to me, to do with a plant or any kind of an installation. We have a real simple storage place for experimental propellants we like a lot. We took a few plastic garbage pails and put them in the ground and put a concrete pad around them for less than $1000 and we have a nice storage area. You have to be sitting right on top of one of those things to get hurt. If one of them goes, the next one doesn't go and it is a nice kind of a design for anything that we can see about it and we wonder why in a lot of installations, instead of trying to get six feet of concrete or something, why you don't just dig a hole in the ground and put it in. I haven't seen anything like that yet. We use the earth as a barricade, so it seems a very natural thing that instead of building the earth up around it, just dig down into it.

Capt. Jenkins: Just dig down. Very simple, isn't it? Dr. Ball, did you have something to mention?

Dr. Ball: I was just wondering, what, if anything, the ASESB is doing about standards of construction for hazardous operations, locations, etc. I've heard "scuttlebut" that you were working on that sort of thing, particularly with respect to bombproof shelters and that sort of thing.

Capt. Jenkins: Mr. Herman, would you like to mention anything about that?

Mr. Herman: I think perhaps Dr. Ball has reference to our underground criteria which we have had a research team working on to develop or at least find out what was in the field and gather it together. This has just recently come off the press; however, it is not for general distribution inasmuch as it is, more or less, part of a study that is under way.

[redacted]

[redacted]

Capt. Jenkins: Is the underground storage technical paper what you had reference to Dr. Ball?

Dr. Ball: Well, the underground is certainly a part of this picture and perhaps a major part. We are still interested in what is the best way to construct things on the surface. We've heard some very interesting things on the part of this Rohm & Haas paper that indicate that by a properly designed structure here of possibly including dual walls with air spaces between and the corners interlocked and that sort of thing and you could probably do a lot better with that than you could standard construction.

Capt. Jenkins: We don't set the standards of construction, Dr. Ball, in our business. We could get into it, with the permission of the Service Members, but I think the Services keep that pretty much in their own hands, the Corps of Engineers in the Army and the civil engineers in the Navy. We ourselves, don't set the uniform construction standards. We pass on what is submitted to us in construction plans during initial design criteria. We are not primarily in the research and development business. We are not a do-all Board in setting design criteria and everything.

Mr. Weintraub: I have another question although it has nothing to do with what Dr. Ball is talking about. I am interested in this problem and maybe someone here is doing something with it. We are building, at present, a very low temperature environmental and physical properties test walk-in room (I guess you would call it) a refrigerated room. The temperature we are being asked to deal with is -75°F and we have been warned by some people in other industries that this can cause a freezing of the lungs, etc. of the people who would have to walk in the room to do certain jobs. My question is, what experience has anyone had with this? What protection can be given to the people who have to go in and, incidentally I should add one more thing, there are fans in there keeping the air circulating very rapidly so you don't get a chance of getting this blanket of protection around you of slightly warmer air. We didn't plan to put more than one man in there at a time although we can watch him, more or less, through some sort of window ports, or should we put two men in, and why "two," etc. Any information on this I would be quite interested in.

Capt. Jenkins: I'm not involved in these test chambers, etc., but I might say that I had considerable experience up in the north during the war and found that I became, overnight, a world-famous expert in cold weather operations. The best thing I could say is that when a man goes into that kind of a temperature, tell him to keep his mouth shut, and breathe through his nose and slowly too, because at 70° below, you can freeze your lungs. Mr. Graham.

Mr. Graham: I would suggest that where he can get practically all the information he wants in reference to that, clothing and everything else, is at QMR&D Command at Nadick, Massachusetts.

[redacted]

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Mr. Bishoff: There are 2 other sources that I can recommend. The Army Environmental Health Laboratory at the Army Chemical Center, Maryland, can give you a lot of information on it. Also, Frankford Arsenal, Philadelphia.

Mr. Murphy: I believe that NOL has done considerable work with their low temperature chamber. Perhaps one of their NOL people could give out some information on it.

Capt. Jenkins: People can survive at those temperatures, however, they won't go in in their "union suits." They can freeze their lungs at that temperature and should breathe through their nose and breathe slowly.

Unidentified: How about your eyes? Will that freeze them?

Capt. Jenkins: They should have the goggles on.

Mr. Weintraub: What about the two man rule?

Capt. Jenkins: It is like sending a man down into a void on board a ship. Never send a man down by himself without having someone there to check on him, a rope around him so you can send another man down to check on him. The two-man rule is a good one, I would say. If there is no reason for two people to be in, it would be the same as in a hazardous area in the explosives business. Don't send ten when you can send one or two. Any other questions?

Mr. Katcher: I don't know whether or not I am jumping the gun on this for you, Capt. Jenkins, but about some of our earlier discussions this morning, I would recommend that in the minutes of the meeting possibly contain information on the overall functions and duties, etc. of some of the things that the ASESB is working on, possibly a listing of the publications of the Board for information such as the one Dr. Ball mentioned that might be of interest to other people here. I have a question that perhaps you can answer. Is it the intention to publish and print in a document the various papers of the subjects presented here today, and also will such organizations as SPIA and distribution list of SPIA get copies of the minutes of today's meeting? Some of the people who are not here today will be interested, I think, in many of the things which have been said. It would be very beneficial to them and, lastly, may I ask, is it contemplated to have another meeting about once a year on this same subject or what are the plans, if any?

Capt. Jenkins: I hope I can answer all of your questions to your reasonable satisfaction. With the vast amount of material which has been presented here and discussed at this Seminar, off hand, I think you'll quite agree, it's going to be quite a job to transcribe and edit it, and fill in the additional comments where necessary, and of course, review the minutes with respect to security. You mentioned something about the functions of the ASESB. I recently mentioned something about that, yesterday I believe. I hope to have some discussions with Capt. Atkins on it, and I'll review that very carefully and will include some more information in there if I can, in addition to what I discussed yesterday which I had hoped would be to your satisfaction. This

production of the minutes with all the length of time it will take to transcribe and edit, might take a couple of months, but the present intent, to answer another question of yours, is to distribute a copy of whatever is finalized to each one of you. Now that can be subject to change but I hope that you or your company will get the information on what we have talked about here these last couple of days. This is an important part of this or any Seminar. Some of the other things I was going to take up here were, first, regarding a future seminar of this nature. We certainly want one next year if there is still that spirit of close harmony among the Services that there is now. It is the Board's intention, of course, to develop this Seminar into a continuing affair, sponsored perhaps by each Service in rotation or even possibly by some other agency. I regret that with my 30 year retirement coming up, I won't have the same active part to play in it next year as in this one. It has been extremely valuable, but we do hope to make this a continuing affair. A lot of people here, I imagine, who have heard mention of various publications during this meeting have taken notes on them; however, we will attempt to include in the minutes, to the best of our ability, what some of these publications are that you would be particularly interested in. Now regarding the SPIA, we are of course going to keep liaison with other groups and other agencies who are working on the problems in this field and especially with a view toward producing, possibly, or coming up with the hazard classification standard or table that we have discussed here, with the hope of getting something out as far as the Board is concerned in the next two months. Mr. Bishoff mentioned some of the work that Army Ordnance is doing with a solid propellants safety manual. We are thinking very much about that. There is still a lot we don't know about the business by any means but we are going to look toward the possibility of getting out a solid propellant safety manual. Mr. Bishoff, I think you or Mr. Queen mentioned to submit requests to you if anyone was interested in any of this.

Mr. Weintraub: One question more on the availability of the publications of the ASESB, if there are any. I don't know whether you have any publications.

Capt. Jenkins: Mr. Roylance, will you make the publications available to him over there?

Mr. Roylance: Yes, if you'll get in touch with me, I'll get them for you.

Mr. Weintraub: Well, it's not from my own standpoint so much as it is from many of the people in the field who need information and are not aware of its availability. Having a list of such publications in the minutes, I think, would serve the purpose quite well.

Capt. Jenkins: Some of the material, of course, is in a limited distribution status. This one on underground storage, is still very much in the process of review and it may never go out as an official document. Two or three of the people here were on that limited distribution and have been given that paper to review. We also have a classified paper on the effectiveness of dividing walls in relation to this propagation business that is very much

under review and I think what you are interested in is the end result. That will be coming out very shortly. As I mentioned before, we have a work group that was just officially put into operation yesterday, we'll add certain pertinent information in this report that goes out then on some of the things which we have available or I'll send them right with the papers, to those people who we know do not have it. Is there anything else for now?

Mr. Endsley: If this problem involves an Air Force item, you might write to the Director of Airmunitions, Ogden Air Materiel Area. They can assist you considerably and the WADC people of ARDC also.

Capt. Jenkins: I think that has taken care of most of what I wanted to say. I hope that you have all enjoyed your visit and that you have profited by it. I know I always feel like a heel in attending any seminar in which I have a part when you don't answer all the questions completely to the satisfaction of the people who are there. I have never attended a seminar that ended up that way, where everyone was completely satisfied, but I do think, speaking for the Board and the military, that this has been an extremely valuable session and we haven't made an attempt to solve all problems by any means but I hope we've laid a lot of the groundwork for future seminars that we will have in the course of time, and which you will carry back to your own organizations which will help the cause of safety a lot.

Mr. Weintraub: Will there be anything like this for liquid propellants?

Capt. Jenkins: Are there any liquid propellants men here; there is another organization who is in that business and there is a liquid propellant safety manual you know. I can't answer that, is there anyone here who can?

Unidentified: We have had several meetings in the past.

Capt. Jenkins: Have they been on this order, with military and civilian?

Mr. Perkins: There is going to be one held in November and it will be held by LPIA, safety is on the agenda, but it will not be specifically on safety.

Capt. Jenkins: I would like to introduce the Board Members who helped put this show on the road: Col. Costabile, Mr. Bishoff, Capt. McKellar, Mr. Roylance, Col. Fincke, Mr. Endsley, and of course, Mr. Marsh enthusiastically went along with the idea when we took it up at a Board meeting. We will keep liaison with other groups and agencies working on problems in this field, especially with a view toward possibly producing a solid propellant safety manual or guide, but there is still a lot we don't know about this business. I want to thank the Navy, especially BuOrd, for taking on the job of hosting this first seminar and Capt. Atkins and the Naval Propellant Plant for making our stay so pleasant. Mr. Perkins, the stenographers and those who have handled the equipment, recorders, mikes and projection material have done a superb job. Thanks to those of you who made presentations, who took such an active part in the discussions, and to those of

you who listened. I hope all of you will take the word back to your [illegible] organizations and your establishments to help the cause of safety in this new field of high energy solid propellants. I know that many of you are going to be remaining over until tomorrow to take this most edifying [illegible] tour of the Naval Propellant Plant. All I can say is, it is too bad you didn't see it first because it is a valuable thing. You are going to see some of the manufacturing processes here and then the big stuff on display. That is about all I have before I turn it over to Capt. Atkins. I would like to say though, to those of you that are leaving, I hope you are going to have a good trip home and God bless you on the way, drive safely.

Capt. Atkins: Well, we certainly have enjoyed having you here, and we've gotten a great deal out of this seminar. There is an awful lot of course, that was not covered, and we look forward to having a meeting with you again next year. We would certainly like to have it back here again if we could swing it. In the meantime, if any of you have time to come down [illegible] and visit with us or write to us, or call us on the phone, we would be glad to hear from you. I want to thank you, Capt. Jenkins, for all the [illegible] that you have given us, and thank you for letting us have it down here. I want to thank you, Capt. McKellar and the Bureau of Ordnance, for bringing us out on the show. Thank you all very much, goodbye and good luck.

DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD
2461 EISENHOWER AVENUE
ALEXANDRIA, VIRGINIA 22331-0600

DDESB-KMC

0 7 JUL 2000

MEMORANDUM FOR DDESB RECORDS

SUBJECT: Declassification of Explosives Safety Seminar Minutes

References: (a) Department of Defense 5200.1-R Information Security Program, 14 Jan 1997

(b) Executive Order 12958, 14 October 1995 Classified National Security Information

In accordance with reference (a) and (b) downgrading of information to a lower level of classification is appropriate when the information no longer requires protection at the originally level, therefore the following DoD Explosives Safety Seminar minutes are declassified:

a. AD#335188 Minutes from Seminar held 10-11 June 1959.
b. AD#332709 Minutes from Seminar held 12-14 July 1960.
c. AD#332711 Minutes from Seminar held 8-10 August 1961.
d. AD#332710 Minutes from Seminar held 7-9 August 1962.
e. AD#346196 Minutes from Seminar held 20-22 August 1963.
f. AD#456999 Minutes from Seminar held 18-20 August 1964.
g. AD#368108 Minutes from Seminar held 24-26 August 1965.
h. AD#801103 Minutes from Seminar held 9-11 August 1966.
i. AD#824044 Minutes from Seminar held 15-17 August 1967.
j. AD#846612 and AD#394775 Minutes from Seminar held 13-15 August 1968.
k. AD#862868 and AD#861893 Minutes from Seminar held 9-10 September 1969.

The DoD Explosives Safety Seminar minutes listed above are considered to be public release, distribution unlimited.

DANIEL T. TOMPKINS
Colonel, USAF
Chairman

Attachments:
1. Cover pages of minutes

cc:
DTIC

AD# 335188 EXECUTIVE RECORD COPY ~~Cy # 69~~

[redacted]

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SUBJECT TO GENERAL DECLASSIFICATION
SCHEDULE OF EXECUTIVE ORDER 11652
AUTOMATICALLY DOWNGRADED AT TWO YEAR
INTERVALS
DECLASSIFY ON 31 December 1973

MINUTES
of the
EXPLOSIVES SAFETY SEMINAR
on
HIGH-ENERGY SOLID PROPELLANTS

Held at the
Naval Propellant Plant, Indian Head, Maryland
on
10-11 June 1959

Armed Services Explosives Safety Board
Washington 25, D. C.

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attendee

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